EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial.

The Allocation of Broadcast Frequencies.

BROADCASTING has brought the States of Europe face to face with a problem of a type entirely different from any which has arisen in the past, a problem daily becoming more acute and requiring to be faced and solved. It is true that broadcasting breaks down the barriers between countries and cultivates a feeling of brotherhood, and, as Mr. Baldwin recently pointed out in a speech at the Guildhall, any enmity that you may be nursing towards the inhabitants of some other State is likely to melt as you listen to them raising their voices in hymns and prayer; but, on the other hand, the feeling of enmity is likely to be restored if he persists in jazzing in a very loud tone just when you yourself wish to indulge in hymns and prayer.

In no other branch of human activity are neighbouring states so interdependent as in broadcasting; frontier guards and tariff walls are alike powerless to keep the electro-magnetic waves either in or out. Whether the waves generated in one country cause interference or not with those generated in other countries depends principally upon their frequency, and it is therefore essential that in the allocation of frequencies the States of Europe should act in unison. This was early recognised and a central parliament was established at Geneva under the name of "L'Union Internationale de Radiophonie." This organisation devised a scheme which came into operation in November, 1926, and this has been the controlling factor in the subsequent organisation of European broadcasting. It was not to be expected, however, that the scheme would prove entirely satisfactory even at the date of its inception, still less that it would not require revision at an early date in view of the rapid growth of interest in broadcasting in countries which, for various reasons, were late in entering the field, and in view also of the great technical developments of transmitting and receiving. Another reason for revising the scheme is the effect of the decisions reached at the recent meetings of the International Radio Conference at Washington.

In July we published an article by M. Siffer Lemoine, the Chief Engineer of the Swedish Telegraph Administration and a member of the Geneva Technical Committee, in which he criticised the 1926 scheme and suggested modifications. We suspect that the subtle humour of his comment that "in spite of its defects, the scheme cannot be regarded as representing a final solution of the problem" was unintentional and due to linguistic difficulties.

We now publish an article by M. W. S.

Heller, the Technical Director of the Polish Broadcasting Company, criticising both the 1926 scheme and M. Lemoine's suggested modifications. The frequency bands allotted to broadcasting by the Washington Conference were hardly up to the expectations of those engaged in this branch of radio communication. Apart from short waves, the bands allotted are as follows: from 200 metres to 545 metres (1,500 to 550 kilocycles per second) except 220 metres (1,365 kc./sec.) which is reserved for shipping; from 1,340 metres to 1,550 metres (224 to 194 kc./sec.) to be used jointly with the air services, and from 1,550 metres to 1,875 metres (194 to 160 kc./sec.) reserved exclusively for broadcasting. The problem of fitting all the broadcast stations of Europe within the available bands without mutual interference is a formidable one. If signal strength always diminished with increasing distance as it does during the day and nobody showed any interest in transmissions from stations beyond a few hundred miles away the problem would be very much simpler. One of the greatest fascinations of wireless consists in receiving programmes from distant continental stations, but this should not be regarded as of the first importance in drawing up schemes of frequency allocation. Both M. Lemoine and M. Heller assume, as indeed they must, that the signal strength falls off with increasing distance according to certain curves, but as everyone knows, very distant stations can often be received at very great strength during the hours of darkness.

Any acceptable scheme must take into account a number of factors of which the principal are: area, population, geographical situation and geophysical character of the country, relative service values of different frequencies and different powers. A country such as Switzerland, in which different languages are spoken in different parts, presents problems which do not arise in a country like Germany, where the same language is spoken from Kiel to Gleiwitz. Such questions as this cannot be settled by any formula, but the weight to be given to area and population, and the relative values of different frequencies can probably be represented by approximate formulæ, and it is with suggestions for such formulæ that MM. Lemoine and Heller deal in their articles. If a is the area and p the population of a country, each expressed as a percentage of the area and population of the whole of Europe, then M. Lemoine suggests $a + 0.5p$ as a measure of the broadcast need of the country. M. Heller does not agree that greater weight should be given to area than to population and suggests $\sqrt{(ap)}$ as a fairer measure of the broadcast need of a country. In neither case is it suggested that the standard of cultural development of a country should be taken into account, nor any question of priority except in the retention of frequencies which have been long in use by stations. These two authorities also differ as to the relative value to be attached to different wavelengths. While both agree that a 500 metre wavelength is better than a 250 metre one and should be reckoned as of greater value in any allocation, M. Lemoine suggests the cube root of the wavelength as a measure of its value, whereas M. Heller maintains that within the range from 200 metres to 545 metres the service value is directly proportional to the wavelength, so that a country might be allocated either one station with a wavelength of 500 metres or two of 300 and 200 metres. Above 1,000 metres he gives them all an equal value.

Little reference is made by either writer to the power transmitted, but M. Heller bases his figures on 25 kilowatts in the aerial, and there is little doubt that the tendency in the future will be to replace a large number of low power stations by a smaller number of high power stations. G. W. O. H.

The Problem of International Distribution of Broadcast Wavelengths.

Proposals of the Polish Broadcasting Company.

I.

THE distribution of wavelengths in Europe, which was based on the Geneva agreement and accepted by the participating powers in November, 1926, had in mind the state of affairs which was in existence at the time that this Convention was signed and the interests of the founders of the Union Radiophonique. The countries which came in later have with difficulty found accommodation in the distribution, especially as no one amongst the privileged members was willing to deprive himself of any advantage for the benefit of the new-comers. This state of affairs, so unfavourable to the non-privileged countries, is a menace not only to the existence of the Union Radiophonique, but is liable to bring about a general disruption of broadcasting. The distribution of wavelengths should be on the principle of absolute equality. The idea of preference for the strongest should be entirely banished as both unjust and impossible to maintain in the ether, except at the cost of complete disruption of any kind of organisation. Any restriction of the right of each country to dispose freely of its title to the ether is impossible, except by mutual agreement between the interested countries.

The system of distribution of wavelengths should be based on the area of the country and the number of its inhabitants, without giving to either of these two factors a superior position, either in area (because radio is for

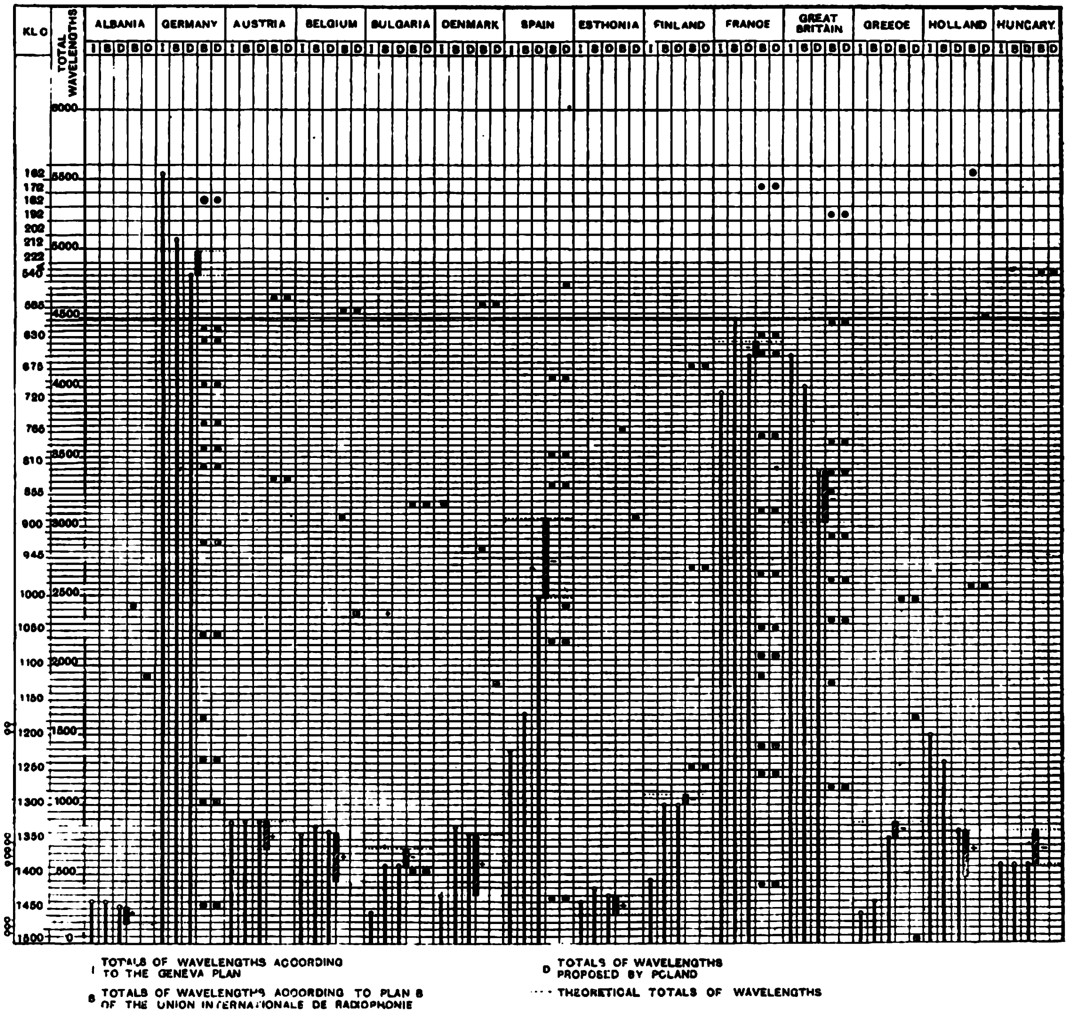
TABLE I.

1. Col.	2. Country.	3. Population in Millions.	4. Area 2 × 1,000 Km.	5. Cols. 3 × 4 in Millions.	6. 2/V of Col. 5.	7. Sum Total "T" of Theoretical Wavelengths.	8. Per Cent.	9. Sum Total of Wavelengths Plan "B."	10. Per Cent. Polish.	11. Sum Total of Wavelengths Plan "D."	**12. Per Cent.**
1	Albania	0,830	27,500	23	4.7	135	0.37	294.1	0.80	**267.8**	**0.72**
2	Germany	63,180	472,037	29,800	172.6	4,977	13.52	5,062.1	13.89	**4,807.9**	**13.05**
3	Austria	6,535	83,833	548	23.4	675	1.83	879.2	2.41	**879.2**	**2.38**
4	Belgium	7,874	30,444	240	15.5	446	1.21	841.7	2.31	**796.3**	**2.21**
5	Bulgaria	5,483	103,146	566	23.7	684	1.85	557.9	1.54	**557.9**	**1.51**
6	Denmark	3,452	43.017	148	12.0	345	0.94	833.3	2.28	**778.3**	**2.11**
7	Spain	22.127	505,208	11,178	106	3,057	8.40	1,650.7	4.54	**2,482.4**	**6.74**
8	Esthonia	1,116	47.459	53	7.2	208	0.56	392.2	1.07	**336,7**	**0.91**
9	Finland	3,526	388,483	1,370	37	1,068	2.89	995.9	2.73	**995.9**	**2.70**
10	France..	40,743	550,986	22,448	150	4,326	11.75	4,493.1	12.33	**4,225.3**	**11.47**
11	Gt. Britain ..	45,370	244,181	11,078	105	3,028	8.23	4,007.5	11.00	**3,391.1**	**9.21**
12	Greece	6,483	140,135	908	30	866	2.34	297.0	0.81	**751.2**	**2.04**
13	Holland	7,526	34,218	258	16	461	1.25	1,303.0	3.58	**800.5**	**2.17**
14	Hungary	8,368	92,928	777	27.8	802	2.17	555.6	1.53	**555.6**	**1.50**
15	Ireland	2,972	68,873	205	14.3	412	1.12	630.4	1.74	**630.4**	**1.71**
16	Italy	40,548	310,090	12,570	112	3,230	8.78	1,866.6	5.12	**2,866.6**	**7.78**
17	Latvia	1,867	65,791	123	11	317	0.86	529.1	1.45	**320.5**	**0.87**
18	Lithuania	2,229	55,658	124	11	317	0.86	314.5	0.86	**314.5**	**0.85**
19	Luxemburg.. ..	0,268	2,586	7	2.6	75	0.20	227.3	0.63	**227.3**	**0.62**
20	Norway	2,788	323,793	902	30	866	2.35	1,287.1	3.53	**1,043.2**	**2.83**
21	Poland	29,589	388.279	11,500	107.2	3,092	6.33	2,470.4	6.78	**2,943.2**	**7.99**
22	Portugal	6,080	91,944	559	23.5	679	1.83	300.0	0.82	**300.0**	**0.81**
23	Roumania	17,153	294,892	5,058	71	2,048	5.56	637.8	1.75	**1,316.2**	**3.57**
24	Sweden	6,074	448,460	2,724	52.1	1,503	4.08	2,735.5	7.51	**1,677.6**	**4.55**
25	Switzerland ..	3,059	41,295	126	11.2	323	0.87	909.0	2.50	**681.8**	**1.85**
26	Czecho-Slovakia..	14,353	140,345	2,014	44.9	1,295	3.51	1,538.0	4.22	**1,538.0**	**4.17**
27	Yugo-Slavia ..	12,492	248,488	3,104	55.7	1,607	4.36	828.3	2.27	**1,357.4**	**3.68**
		362,085	5,244,069	**118,411**	**12,777.4**	**36,842.8**	**100%**	**36,437.3**	**100%**	**36,842.8**	**100%**
28	Not provided for in the Geneva plan							**405.5**			
								36,842.8			

the service of man), nor the number of inhabitants (because the density of population facilitates the task of distribution).

An analysis of the information contained in Table I indicates the impossibility of basing the distribution of wavelengths on the product of the area of a country and the number of its inhabitants. In such a case the lesser powers would be left with nothing, gressive system, that is to say, giving advantages to the weaker at the cost of the stronger, on the same lines as progressive taxation is arranged. Calculation shows that this can be arrived at by replacing the product of the number of inhabitants and the surface of the country by the square root of this product. This would work much better than a haphazard allocation of positions

TABLE II.—CHART GIVING DATA



or almost nothing. This can be remedied on the basis of the argument we have already raised that equality should come before everything, working on the basis of a progressive system … to the small Powers. The analysis of such a distribution shows in many cases agreement with the existing state of affairs. The differences which are noted are easily ex-

possess all the necessary means for the sure and rapid development of their broadcasting.

II.

Efficiency of Wavelengths.

The comments attached to the present memoir and based on the publications of P. P. Eckersley, of the Institution of Electrical Engineers, prove that within the limits of broadcasting wavelengths, that is to say, between 540 and 1500 metres, attenuation remains proportional to wavelength, provided that intensity does not vary and does not exceed 2.5 mV/m; in other words, up to the limit of receptivity with a crystal detector. With a voltage below this value reception becomes insufficient from the point of view of service and measurement, too, becomes uncertain.

A comparison could also be made with the proposals of M. Lemoine published in *E. W. & W. E.* As a result of the relationship established between attenuation and wavelength, the efficiency of wavelengths from the point of view of utility may be expressed by the sum total in metres. This simplifies enormously the assessment of the value of wavelengths of each country and also easily establishes their mutual reciprocity.

To wavelengths above 1,000 metres, and particularly the seven wavelengths between 1351.3 and 1,852 metres, we need not trouble to apportion values, because the variation from this rule would be so slight. The coefficient which limits the usefulness of wavelengths from the point of view of the service of broadcasting is due to the growing difficulties of reception. The falling-off of long-wave reception results from the increased damping of the circuit of crystal receivers, the field strength remaining the same. This necessitates the use of external aerials, which appreciably hinders the popularity of broadcasting.

For this reason we regard wavelengths beyond 1,000 metres as equivalent and of the same order of efficiency as those of 1,000 metres; although this coefficient is only chosen as a compromise it is adaptable to actual conditions, and a variation up to 50 per cent. will not require any appreciable modifications to the plan of distribution. Table I, column 7, shows us the sum total of wavelengths in metres, available for each country, the total being 36,842.8 metres, placed at the general disposal of broadcasting, and divided into 98 exclusive wavelengths. The six long wavelengths are counted as equivalent to a wavelength of 1,000 metres, the seventh long wavelength (the Russian wavelength) not having been taken into account.

Table II shows us the total of wavelengths of each country according to the Geneva plan, proposals of the Commission Technique de l'Union Internationale, and the effect which would result from the principles indicated in this Memoir. Certain countries are favoured at the expense of their neighbours, when it would have been easy to have avoided it, but the basis of this proposal is in agreement with the present state of affairs and would introduce only slight modifications, and in the case of some countries no changes at all. The result is arrived at by applying impartial methods of treatment to all members of the Union Radiophonique and eliminates all chance.

This memoir does not attempt to merely modify the present arrangement for the distribution of wavelengths by replacing it with the proposal "D," but endeavours to emphasise the necessity for accepting certain principles in the absence of which a fair and proper distribution must be impossible.

Comments on the Above Proposals.

By W. S. Heller.

(Technical Director of the Polish Broadcasting Company.)

THE question of the allocation of wavelengths for European broadcasting stations is at present especially important, having regard to the limitation of the wavelength band decided upon by the Washington Conference and also the increas-

ing demands of new stations for broadcasting service. This question has been recently discussed by M. S. Lemoine in Volume V, No. 58, *E. W. & W. E.*

The principle of distribution suggested by M. S. Lemoine will find full approval as a first serious effort to find a practicable and just solution. The present system of allocation known as the Geneva Plan, now in use, is based on priority, and is the reason for various troubles. A new system of distribution must be undoubtedly introduced on a common basis resulting from the value of area and population. Consequently a multiplication coefficient should be used for the calculation of the numerical value, but it is not satisfactory to take the full area and only half of the population into account, as is done by M. Lemoine, because the population and not the area is the object of the service. A trial of such multiplication coefficients indicates, as would be expected, a great privilege for the larger in comparison with the smaller countries. To equalise this difference to the rightful level it is proposed to take the square root of the product of area and population. In this way a comparison can be found, which corresponds with the actual conditions and gives desirable proportions. Comparing the results of this theory with the percentage values estimated by M. Lemoine some great differences will be noticed, which are caused by the especially great areas taken in these cases (Finland, Norway and Sweden).

Service Value for Different Wavelengths.

Curves prepared by Captain P. P. Eckersley (*Journal of the Institution of Electrical Engineers*, Vol. 66, No. 377, published in February, 1928) give results as shown in the table above.

For 5GB Station and 25 kW. Aerial Output.

Field strength	30	25	20	15	10	8	6	4	mV./m.
Distance for 1,040 kcl. ..	11.5	12.5	14.5	18.0	22.5	26.0	30.0	36.0	miles.
,, ,, 610 kcl. ..	20.0	22.0	26.0	31.0	38.5	43.5	50.0	65.0	miles.
Proportional ratio	1.74	1.76	1.79	1.72	1.71	1.67	1.67	1.80	

The reciprocal ratio of the frequencies 1,040/610, or the direct ratio of the wavelengths, is 1.71 and is equal to the ratio of the distances for equal field strength within 5 per cent. This principle can be approximately extended for broadcasting wavelength range from 200 m. to 550 m. and field strength values down to 2 mV./m. Smaller field strength values are not suitable for broadcasting service. The above figures are based on 25 kW. in the aerial, and it can be assumed that with the development of Broadcasting an increase of the power used for stations will take place.

Since direct proportion exists between service values and wavelengths, a comparison between the total sums of the wavelengths is also possible; in other words, since average service values depend upon wavelengths or sum of the wavelengths in a direct ratio, the total sum of the wavelengths corresponds with the service value of the wavelengths allocated to any given country. With regard to the longer waves, above 1,000 m. no experiments have been carried out to determine and to compare their service values. Probably the same direct proportion holds approximately, but it does not seem reasonable to bring it into consideration. The service value of longer wavelengths is limited by less favourable reception conditions. The crystal detector reception of longer wavelengths depends, assuming the same values of field strength as for the shorter wavelengths, upon better constructed aerials and H.F. circuits in order to counteract the increased damping effect. Therefore the six possible longer wavelengths of the broadcasting band are estimated as having the same service values as the 1,000 m. wavelength. This consideration seems to be reasonable, until further experiments have been made to determine the actual service values.

There are fundamental differences between the above valuation system and that proposed by M. S. Lemoine. Taking the service value of a 200 m. wavelength as

unity, then a

300 m. wave, according to M. Lemoine is	..	1.15 ;	and accord. to this proposal	..	1.5
428.6 m.	„	„	1.30 ;	„	„	2.14
500 m.	„	„	1.37 ;	„	„	2.5
1,563 m.	„	„	2.00 ;	„	„	5.0

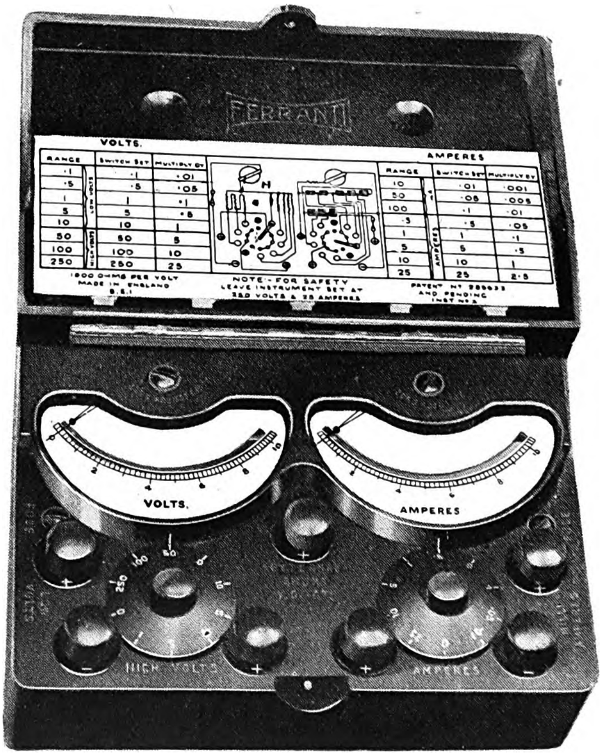
The results estimated by M. Lemoine are probably for much smaller field strengths and depend upon correspondingly smaller aerial outputs (Fig. 2 and 3, *E. W. & W. E.*, Vol. V, No. 58). It seems to be certain that the valuation system here explained corresponds much more closely than the system of M. Lemoine to the results being obtained at present in the erection and valuation of broadcasting stations. No special difficulties will be met in the realisation of this system of valuation, as can be seen from the tables (see pp. 3, 4, and 5).

It is possible that, in the future, progress in the research of radiation and in the erection of high-power stations will lead to a correction of the valuation plan outlined above. For all that, it is obviously desirable to find and to introduce a system of distribution and valuation of the waves which on the basis of present technical development can be accepted by every member of the Union.

Ferranti Multi-Range Test Set.

THE Ferranti multi-range test set illustrated comprises two 2½ in. 8-range moving-coil instruments with knife-edge pointers and mirror scales fitted in the same case of moulded insulating material and calibrated, respectively, to read volts and amperes independently, each instrument having a separate 10-way switch to select the required range. The self-contained ranges included are :--

Volts.			Amperes.
0–0.1	..	..	0–0.01
0–0.5	..	..	0–0.05
0–1	..	..	0–0.1
0–5	..	..	0–0.5
0–10	..	..	0–1
0–50	..	..	0–5
0–100	..	..	0–10
0–250	..	..	0–25



As the resistance of the voltmeter is 1,000 ohms per volt, an additional self-contained range of 0–1 mA. can be obtained on the voltmeter using the low-range terminals with the switch set at 0.1 volt. Moreover, an additional terminal is provided to permit of the use of external shunts having the full load volt-drop of 75 mV., thus extending the range of the ammeter indefinitely.

The terminals can be connected so as to put the two instruments in series when, as the ammeter has a full scale consumption of 6 mA., one-third of the maximum reading (2 mA.) represents 500 volts, thus giving an additional voltage range. Although the voltmeter will be overloaded during such a test, its exceptionally robust construction prevents it from being damaged.

There is a replaceable fuse in circuit for each volt and milli-amp. reading, the ammeter is compensated for temperature, and all its shunts are solidly connected, thus obviating internal variable contact resistance errors.

For the testing of radio valves, two plugs can be supplied each with a set of leads permanently attached. One plug is used when it is desired to measure anode current and filament voltage ; the other plug being used for the measurement of grid bias voltage, and filament current and also to give an indication of continuity of the grid circuit.

Each valve plug is provided with an engraved plate showing the quantities which can be measured, and the free ends of the leads are marked to indicate to which terminal of the test set they are to be connected.

Some Remarks on Ultra Short Wave Broadcasting.*

By Balth. van der Pol, D.Sc.

(Radio Research Department, Philips Radio, Eindhoven, Holland.)

A. Emission.

WHEN the range of wavelengths between 20,000 and 1,000 metres is denoted by "long" waves, the waves between 1,000 and 100 metres by "short" waves and the waves between 100 and 10 metres are called "ultra-short," it will be clear that the ratio between the commercial frequency of 50 cycles and the frequency of "long" waves is of the same order as the ratio between the frequency of "long" waves and the frequency of "ultra-short" waves.

Therefore, it is obvious that certain technical considerations have to be borne in mind in the construction of an ultra-short wave telephone transmitter which are not to be adhered to primarily in the working with much lower frequencies.

Outstanding amongst these considerations is the constancy of frequency (wavelength). Not only constancy of frequency in the course of, say, one hour, but especially during *modulation*. The normal ideal modulation consists of *pure amplitude modulation*. This ideal aim is most clearly expressed by a few mathematical symbols. When we confine ourselves to anode potential modulation and when the variable part of the air pressure in front of the microphone is given by

$$f(t) \qquad \ldots \qquad (1)$$

(which therefore is a low-frequency function) the ideal modulation consists of making the anode tension V_a (which, without modulation, would be a constant $V_a = V_{a0}$) apart from this constant value an exact image of the air pressure in front of the microphone, *i.e.*:

$$V_a = V_{a0} + a f(t) \qquad \ldots \qquad (2)$$

where a is some constant.

Again, let the antenna-current $i_{\text{ant.}}$ corresponding to the anode potential V_a be

$$i_{\text{ant.}} = \beta V_a \sin \omega t \qquad \ldots \qquad (3)$$

where again β is a constant and ω the angular frequency of the transmitter.

From (2) and (3) it follows that the antenna-current obtained with ideal amplitude modulation is given by

$$i_{\text{ant.}} = \beta\{V_{a0} + a f(t)\} \sin \omega t \qquad \ldots \qquad (4)$$

(4) expresses the fact that the variable part of the amplitude of the high frequency antenna-current is an exact image of the variable part of the air pressure in front of the microphone.

However, a serious difficulty arises which, especially with ultra short waves, is to be borne in mind. For it is a well-known fact, that the angular frequency ω of an ordinary oscillatory circuit is *not* given by

$$\omega^2 = \frac{1}{LC}$$

but by

$$\omega^2 = \frac{1}{LC} - \frac{r^2}{4L^2} = \omega_0^2\left(1 - \frac{r^2C}{4L}\right)$$

where
$$\omega_0^2 = \frac{1}{LC}$$

represents the ideal frequency without the correction due to the presence of the resistance r.

As a triode characteristic is always curved (which curvature we make use of in detection and modulation) it is obvious that, when V_a is varied, every time a different differential resistance will be present in the system, resulting in a different frequency correction due to the resistance terms in the equations. Thus the momentary frequency ω will also depend on the momentary anode potential, *i.e.*:

$$\frac{\delta\omega}{\delta V_a} \neq 0$$

or

$$\omega = \omega_0\{1 + \phi(V_a)\}$$

* Report to the Technical Committee of the "Union Internationale de Radiophonie."

where $\phi(V_a)$ is a function of the anode potential having the character of a frequency correction which is intimately connected with the curvatures of the grid- and anode-characteristics.

Thus we obtain for the expression of the momentary antenna-current instead of (4):

$$i_{\text{ant.}} = \beta\left\{V_{a_0} + a f(t)\right\} \sin\left\{\omega_0 \int (1 + \phi(V_a))\, dt\right\} \quad .. \quad (5)$$

This formula clearly shows that, during modulation, it is not only the amplitude of the antenna-current

$$\beta\{V_{a_0} + a f(t)\}$$

which is varied in audio rhythm, but that *also* the frequency

$$\omega_0(1 + \phi(V_a))$$

varies unintentionally. Therefore, unless special precautions are taken, the transmitter does not only produce the intended *amplitude modulation*, but also an unintended *frequency modulation.*

The pronounced hum often audible during the reception of badly designed amateur ultra short wave transmitters is no doubt due to this latter *frequency modulation*, even when the smoothing system of the transmitter is sufficient to cause a negligible *amplitude modulation.* Especially with faint signals the receiver, when used with nearly critical retroaction, has a very sharp resonance curve. The *frequency modulation* of the transmitter may be the cause that, even without appreciable *amplitude modulation*, the high frequency of the incoming signal varies periodically—with the frequency of the hum—to such an extent, that periodically the receiver is in tune and out of tune several times per second (with the frequency of the hum). This would cause a very pronounced hum in the telephones.

Therefore, the first requirement of an ultra short wave telephone transmitter is *constancy of frequency*, not only from day to day, but also during modulation, *i.e.*, the absence of *frequency modulation.*

As is well known, this constancy of frequency is obtainable through the use of

(*a*) piezo electric quartz oscillators (when necessary temperature controlled);

(*b*) the complete elimination of the reaction from the power stage on the "drive."

A short explanation of the reason why the frequency of quartz crystals is affected only to a very small extent by external means may be given here. The equivalent electrical circuit of a piezo electric quartz crystal is as given in Fig. 1.

It consists of a big inductance L of the order of 50 henrys in series with a very small capacity C_1 of the order of 0.05 $\mu\mu$F and a series resistance r of, say, 2,500 ohms.

When the crystal is connected to a triode the system is shunted by a capacity C_2 of the order of 5 or 10 $\mu\mu$F. The value of the

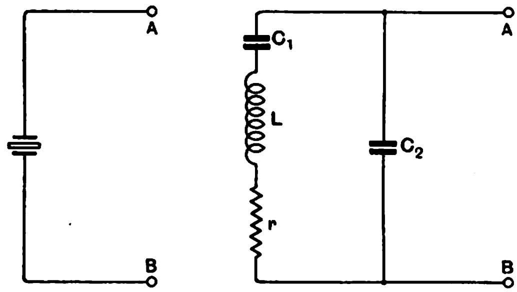


Fig. 1.

relatively large capacity C_2 (compared with C_1) has little influence on the frequency ω of the circuit rLC_1C_2, which is given by the formula

$$\omega^2 = \frac{1 + C_1/C_2}{LC_1(1 + r^2C_1/4L)}$$

but the fact that C_2, across which the external circuit is connected, is much greater than C_1, gives *a very loose capacity coupling to a very low damped oscillatory* circuit, the logarithmic decrement δ being about

$$\delta = 2\pi \cdot \frac{r}{2\omega L} \doteqdot 0.00025.$$

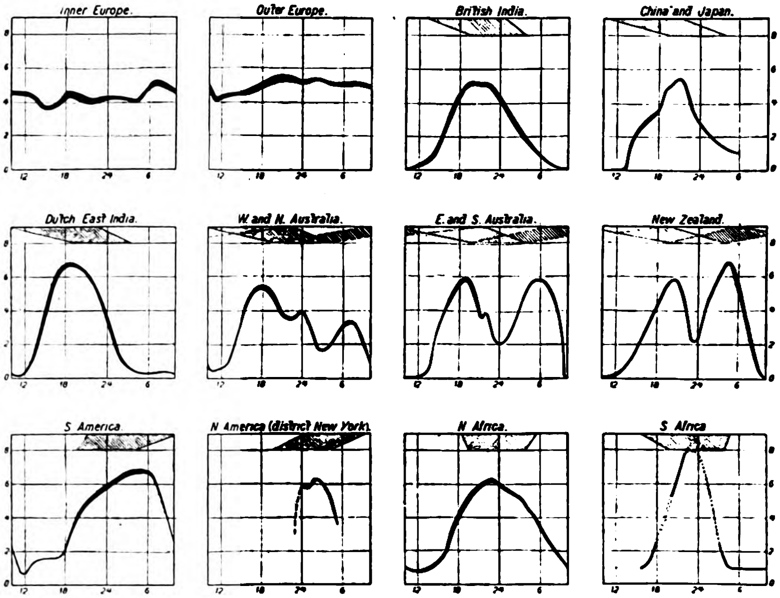
As the terminals A,B are the only ones accessible, one can use this equivalent electrical system with an extremely loose coupling only, and it is therefore impossible to influence the system by external means to any great extent.

B. Transmission.

The transmission phenomena of ultra short waves are extremely complex and partly still little understood. It is therefore out of the question to give any detailed or

complete account of it here. However, some results of a continuous 24-hour emission (July 26th-27th, 1927) of the ultra short wave telephony station PCJJ of *Philips Radio Laboratory* (Eindhoven, Holland) will be of interest. The station worked with a wavelength of 30·2 metres, and the power supplied to the last stage was 20 to 25 kilowatts. The above-mentioned 24-hour transmission was announced beforehand, and the many correspondents from all over the world were asked to send detailed reports of received intensity as a function of the time.

Many hundreds of letters were received and each report was treated as follows. According to the data supplied by each correspondent each hour of the day was given a number representing the intensity of reception. These numbers ranged from 0 (nothing audible), 1 (carrier just audible), etc. . . . to 9 (extremely strong reception). Afterwards the world was divided in 12 parts as indicated in the accompanying graphs, and all the numbers obtained from the data supplied by correspondents living in the same " part " of the world were averaged. The accompanying graphs illustrate the results thus obtained. The abscissa represent the time (G.M.T.) and the ordinates the averaged signal strength.



Obviously this procedure is a very rough one and as the correspondents used quite different receiving sets no very accurate results can thus be expected. The results, however, are in the main quite consistent. " Inner Europe " is defined as England, Holland, Denmark, Belgium, France and Germany, the rest of Europe being taken as " Outer Europe." The shaded portions on the top of each diagram represent in the well-known manner the distribution of light and darkness between transmitter and receiver. The thickness of the curves is an indication of the number of reports received for every hour.

The following conclusions may be drawn from the graphs. It is seen that the average signal strength in " Outer Europe " is somewhat higher than in " Inner Europe " pointing towards a skipped distance. British India and China and Japan have their maximum of reception roughly at the period where the complete track of the waves is in darkness. W. and N. Australia and E. and S. Australia show *two* main maxima of reception, the second maximum being higher in E. and S. Australia than in W. and N. Australia. This second maximum is still more pronounced in the reception in New Zealand. No doubt this second maximum is due to the waves travelling in western direction round the globe. A small secondary maximum after the first main maximum is present in the whole of Australia. It occurs one hour after sunrise in Australia and seems to occur quite regularly. The transmission to S. and N. America seems also best when the whole track is in darkness and the same rule applies to N. and S. Africa.

As stated above, the figures given only apply to a wavelength of 30.2 metres and will be quite different for other frequencies.

C. Reception.

Both ordinary retroactive sets specially designed for ultra high frequencies, and superheterodyne sets can be used for re-

ception. The width of the received band in a superheterodyne set is obviously determined mainly by the intermediate frequency amplifier, and therefore the same rules are valid for these sets whether used for the short wave or ultra short wave band. On the other hand, the selectivity of a simple one-stage retroactive receiving set, as used quite extensively by many listeners, depends very markedly on the amplitude of the incoming signal. Measurements in *Eindhoven* have shown that signals from stations like *Schenectady* and *Bandoeng* (Java) when received with a retroactive receiver adjusted for maximum intensity, have such an amplitude that another signal of the same intensity but at 10 to 15 kilocycles separation would be inaudible in the headphones. However, the theory as well as the experiment shows that, when the signals are stronger, the selectivity of such a simple receiving set is much reduced.

We feel quite sure that the constancy of frequency of the transmitter (the absence of *frequency modulation*) is a very important factor in determining the quality of reception, especially with ultra short waves. A relatively simple theoretical consideration, which will not be given here, clearly shows that, when the waves reach the receiver along more than one path, the frequency modulation may, even with a flatly tuned receiver, be a pronounced source of distortion.

As the effect of frequency modulation was early recognised, special care was taken in the design of the station PCJJ that this source of distortion would be absent as much as possible. From the many thousands of letters received from correspondents from all over the world during a period of about one year and a half, the general conclusion may be drawn—with the present state of the technique—that at the time of maximum reception the quality of reception generally improves with the distance (also the fading being less) and may be such—though not yet yielding a highly artistic satisfaction—that the greater part of the listeners receive the station with much enthusiasm. Especially many letters reached us from grateful listeners living in the Dutch East Indies relatively far away from the civilised towns. Though the number of these listeners may not be high, the great appreciation they show for enabling them to listen to their mother country (even though the quality of reception is not yet ideal) can hardly be overestimated.

As to the most advisable frequency difference between two wireless telephone transmitters for ultra short waves, relatively few data are so far at hand. In view of the resolutions adopted at Washington the wavelength of PCJJ was recently changed from 30.2 metres to 31.4 metres. It happens that this frequency is relatively near the one of Schenectady, the difference according to some preliminary measurements made at Eindhoven being 38.7 kilocycles. Though often both stations worked simultaneously, so far only *one* complaint has reached us about mutual interference.* In view of the difficulties encountered with regard to the constancy of frequency in the waveband 300–600 metres it would, according to the author, be strongly advisable that all ultra short wave broadcasting stations to be erected in the future should be obliged to use crystal control exclusively. At the same time, this would greatly reduce or eliminate altogether *frequency modulation.* Whenever possible the crystal should be mounted in a thermostat, so as to keep its temperature and frequency constant. Under these circumstances, a frequency separation of about 30 kilocycles would be sufficient.

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* Since writing this report, more complaints about mutual interference between Schenectady and Eindhoven have reached us. The matter is being investigated further.

P.S.—In writing this note free use was made of the following papers:

BALTH. VAN DER POL.—Free and forced triode oscillations. *Radio Review I*, 701, 1920.

J. R. CARSON.—Notes on the theory of modulation, *Proc. Inst. of Radio*, Eng. 10, 57, 1922.

R. BOWN, K. MARTIN, R. POTTER.—Some studies in Radio broadcast-transmission. *Proc. Inst. of Radio*, Eng. 14, 57, 1926.

BALTH. VAN DER POL.—Het gebruik van piëzo-electrische kwarts kristallen in de draadlooze Telegrafie en Telefonie. *Gedenkboek Ned. Ver. voor Radiotelegrafie*, 1926, 293.

BALTH. VAN DER POL.—Forced oscillations in a circuit with non-linear resistance (reception with reactive triode). *Phil. Mag.* 3, 65, 1927.

BALTH. VAN DER POL.—Enkele physische beschouwingen over ultra korte golven, mede in verband met de uitzendingen van het Philips' Radio Laboratorium. *Tijdschrift van het Ned. Radiogenootschap* III, 161, 1927.

The High-Frequency Resistance of Toroidal Coils.

By S. Butterworth, M.Sc.

1. THE characteristic property of a toroidal coil is its complete astaticism, that is to say, its magnetic field lies entirely within the coil and there is therefore no electromagnetic interference between the coil and neighbouring coils.

Although in certain cases toroidal coils are essential, the writer cannot recommend this type of coil in the construction of wireless receiving sets for the reason that, bulk for bulk, a well-designed toroidal coil has more than twice the high-frequency resistance of a well-designed solenoidal coil. This would not be a sufficient reason if with the latter type of coil it were impossible to avoid electromagnetic interference, but it is readily possible to arrange three solenoidal coils to have no mutual interference by putting their centres in line and their axes in mutually perpendicular directions. Toroidal coils should only be employed when one cannot afford the slightest trace of electromagnetic interference, for example, when it is desired to construct an oscillating set to inject a very

TABLE I.

VALUES OF THE FUNCTIONS F AND G.

d = diameter of wire (cms.) ; ρ = resistivity (c.g.s. units) ; f = frequency (cycles per sec.) ;
$z = \pi d\sqrt{2f/\rho}$. For copper of resistivity 1,700 c.g.s., $z = 0.1078\, d\sqrt{f}$.

z	$1+F$	G	z	$1+F$	G	z	$1+F$	G	z	$1+F$	G
0.0	1.000	—	2.5	1.175	0.2949	5.0	2.043	0.755	10.0	3.799	1.641
0.1	1.000	—	2.6	1.201	0.3184	5.2	2.114	0.790	11.0	4.151	1.818
0.2	1.000	$z^4/64$	2.7	1.228	0.3412	5.4	2.184	0.826	12.0	4.504	1.995
0.3	1.000	—	2.8	1.256	0.3632	5.6	2.254	0.861	13.0	4.856	2.171
0.4	1.000	—	2.9	1.286	0.3844	5.8	2.324	0.896	14.0	5.209	2.348
0.5	1.000	0.00097	3.0	1.318	0.4049	6.0	2.394	0.932	15.0	5.562	2.525
0.6	1.001	0.00202	3.1	1.351	0.4247	6.2	2.463	0.967	16.0	5.915	2.702
0.7	1.001	0.00373	3.2	1.385	0.4439	6.4	2.533	1.003	17.0	6.268	2.879
0.8	1.002	0.00632	3.3	1.420	0.4626	6.6	2.603	1.038	18.0	6.621	3.056
0.9	1.003	0.01006	3.4	1.456	0.4807	6.8	2.673	1.073	19.0	6.974	3.233
1.0	1.005	0.01519	3.5	1.492	0.4987	7.0	2.743	1.109	20.0	7.328	3.409
1.1	1.008	0.02196	3.6	1.529	0.5160	7.2	2.813	1.144	21.0	7.681	3.586
1.2	1.011	0.03059	3.7	1.566	0.5333	7.4	2.884	1.180	22.0	8.034	3.763
1.3	1.015	0.04127	3.8	1.603	0.5503	7.6	2.954	1.216	23.0	8.388	3.940
1.4	1.020	0.0541	3.9	1.640	0.5673	7.8	3.024	1.251	24.0	8.741	4.117
1.5	1.026	0.0691	4.0	1.678	0.5842	8.0	3.094	1.287	25.0	9.094	4.294
1.6	1.033	0.0863	4.1	1.715	0.601	8.2	3.165	1.322	30.0	10.86	5.177
1.7	1.042	0.1055	4.2	1.752	0.618	8.4	3.235	1.357	40.0	14.40	6.946
1.8	1.052	0.1265	4.3	1.789	0.635	8.6	3.306	1.393	50.0	17.93	8.713
1.9	1.064	0.1489	4.4	1.826	0.652	8.8	3.376	1.428	60.0	21.46	10.48
2.0	1.078	0.1724	4.5	1.863	0.669	9.0	3.446	1.464	70.0	25.00	12.25
2.1	1.094	0.1967	4.6	1.899	0.686	9.2	3.517	1.499	80.0	28.54	14.02
2.2	1.111	0.2214	4.7	1.935	0.703	9.4	3.587	1.534	90.0	32.07	15.78
2.3	1.131	0.2462	4.8	1.971	0.720	9.6	3.658	1.570	100.0	35.61	17.55
2.4	1.152	0.2708	4.9	2.007	0.738	9.8	3.728	1.605	Large	$(\sqrt{2z}+1)/4$	$(\sqrt{2z}-1)/8$
2.5	1.175	0.2949	5.0	2.043	0.755	10.0	3.799	1.641	—	—	—

small measurable electromotive force into another circuit. For this reason it is considered worth while to obtain formulæ for the high-frequency resistance of toroidal coils and thence deduce the conditions for minimum resistance.

2. The theory of the losses in inductance coils in general has been discussed by the present writer in a series of articles which appeared in *E. W. & W. E.* in April, May, July and August, 1926. The results of this theory so far as they affect toroidal coils are summarised below.

The general formula for the high-frequency resistance of a coil in which the turns are not too closely packed is

$$R_c = R\left\{1 + F + \left(\frac{KNd}{2D}\right)^2 G\right\} \quad .. \quad (1)$$

when the coil is wound with solid wire, and

$$R_c = R\{1 + F + (k/d_0{}^2 + \tfrac{1}{4}K^2N^2/D^2)\, n^2d^2G\} \quad .. \quad (2)$$

when the coil is wound with stranded wire.

In these formulæ the symbols have the following interpretation :—

R_c = H.F. resistance.
R = D.C. resistance.
N = Number of turns.
n = Number of strands.
d = Diameter of one strand.
d_0 = Overall diameter of stranded wire.
D = Overall diameter of coil.

The units of measurement of the resistances and the various diameters do not matter, as if R is in ohms, R_c is also in ohms, while since the diameters enter as ratios (d/d_0 and d/D) we can express the diameters as all in inches or all in millimetres indifferently.

The factors F and G depend upon the frequency, f, and the diameter, d, of a single strand. We first calculate a quantity z from the formula $z = d\sqrt{f}/92.8$, d in this formula being in mms. and the frequency in cycles per second, and then read off F and G from Table I.

The factor k entering only in the stranded wire formula depends on the number of strands and has the following values :—

n	1	3	9	27	large
k	0	1.55	1.84	1.92	2

The factor K depends upon the type of coil. Tables of K for solenoidal and disc coils have been given in the above-mentioned articles, but K has not hitherto been tabulated for toroidal coils.

The value of K is calculated by determining the mean square field acting on the wire of the coil when a current I is flowing. If, then, H_m be the root mean square field

$$K = H_m D/NI,$$

in which D is the overall diameter of the coil and N is the number of turns.

For a toroid the field at any point in the winding section is $2NI/r$, where r is the perpendicular distance of the point from the axis of the toroid. Also, for a single layer toroid, we must take the field acting on the wire as half that just inside the winding section, so that to determine the mean square field we must integrate N^2I^2/r^2 round one turn and divide by the length of the turn. The integration is quite straightforward for toroids of circular or rectangular winding section, and we are led to the following formulæ for K.

For a single layer toroid of circular section

$$K = 2(1 - x)^{\frac{1}{2}}/(1 - 2x)^{\frac{3}{4}} \quad .. \quad (3)$$

TABLE II.

COIL FACTORS FOR SINGLE LAYER TOROIDS (CIRCULAR SECTION).

D_s/D.	L_o.	K.	S.	Relative H.F. Resistances.	
				Toroid.	Solenoid.
0.05	0.00826	2.110	4.33	13.4	3.01
0.10	0.03502	2.243	2.23	7.0	2.05
0.15	0.08382	2.409	1.55	4.92	1.64
0.20	0.1596	2.602	1.21	3.86	1.43
0.25	0.2695	2.913	1.04	3.31	1.33
0.30	0.4244	3.327	0.95	2.98	1.24
0.35	0.6426	3.978	0.92	2.83	1.20
0.40	0.9599	5.180	1.00	2.90	1.16
0.45	1.468	8.341	1.28	3.54	1.14

D = Overall diameter of toroid.
D_s = Diameter of winding section.
L_0 = Inductance factor in formula (6).
K = Proximity factor in resistance formulæ (1) and (2).
S = Factor used in determining the optimum diameter of wire.

in which x is the ratio of the diameter D_s of the winding section of the toroid to the overall diameter D.

For a single layer toroid of rectangular section of radial depth t, axial length b and of overall diameter D:

$$K = 2\{1 - 2x + 2x^2y/(x+y)\}^{\frac{1}{2}}/(1-2x) \;.. \quad (4)$$

in which, now, $x = t/D$ and $y = b/D$.

The relative resistances refer to equally compact coils using the optimum diameter of wire for each shape. The corresponding values for solenoids refer to the solenoid in which the toroid will just fit, that is, the solenoid has diameter D and winding length D_s.

SINGLE LAYER TOROIDS OF RECTANGULAR WINDING SECTION.

TABLE III.

VALUES OF FACTOR L_0 IN FORMULA (6.)

b/D / t/D	0.125	0.250	0.375	0.500
0.1	0.0558	0.1116	0.1674	0.223
0.2	0.1278	0.256	0.383	0.511
0.3	0.229	0.458	0.687	0.916
0.4	0.402	0.805	1.208	1.660

TABLE IV.

VALUES OF FACTOR K IN FORMULÆ (1) AND (2).

b/D / t/D	0.125	0.250	0.375	0.500
0.1	2.25	2.25	2.26	2.26
0.2	2.65	2.67	2.69	2.70
0.3	3.37	3.47	3.54	3.58
0.4	5.25	5.68	5.96	6.14

The values given in column 3 of Table II are calculated from formula (3) and the values given in Table IV are found from formula (4).

If the toroid has m layers the tabulated values of K should be multiplied by

$$\{1 + \tfrac{1}{3}(1 - 1/m^2)\}^{\frac{1}{2}}.$$

3. The formula for the inductance of a toroid of circular winding section is

$$L = 2\pi N^2\{D_m - (D_m^2 - D_s^2)^{\frac{1}{2}}\}/1000 \quad (5)$$

in which L is the inductance in microhenrys and D_m is the mean diameter of the toroid. Writing $D_m = D - D_s$ we may put

$$L = L_0N^2D/1000 \quad .. \quad .. \quad (6)$$

in which

$$L_0 = 2\pi x^2/\{1 - x + (1-2x)^{\frac{1}{2}}\}, \ (x = D_s/D) \;.. \; (7)$$

From (7) the values of L_0 given in column 2 of Table II have been calculated.

TABLE V.

VALUES OF FACTOR S FOR DETERMINATION OF OPTIMUM DIAMETER.

b/D / t/D	0.125	0.250	0.375	0.500
0.1	1.78	1.25	1.03	0.89
0.2	1.38	0.98	0.81	0.70
0.3	1.31	0.95	0.80	0.70
0.4	1.54	1.18	1.01	0.89

TABLE VI.

RELATIVE H.F. RESISTANCES OF EQUALLY COMPACT COILS.

b/D / t/D	0.125	0.250	0.375	0.500
0.1	6.5	5.5	5.4	5.5
0.2	4.8	3.7	3.4	3.4
0.3	4.5	3.2	2.9	3.0
0.4	4.8	3.6	3.2	3.5
Enveloping solenoid	1.81	1.32	1.18	1.13

For toroids of rectangular winding section

$$L = 2N^2b\{\log_e D - \log_e (D - 2t)\}/1000 \quad (8)$$

so that if we throw this into the form (6)

$$L_0 = -2y \log_e (1 - 2x), \begin{matrix} y = b/D \\ x = t/D \end{matrix} \quad .. \quad (9)$$

From (9) we get the values given in Table III. As regards the values of L_0, these hold equally for single layer and multi-layer coils.

4. Best Diameter of Wire.

A study of the resistance formula shows that the first part, $R(1 + F)$, diminishes as the diameter of the wire increases, while the second part, $R\left(\frac{KNd}{2D}\right)^2G$, increases with increase in the diameter of the wire. For a certain diameter of wire (depending upon the frequency) the resistance passes through a minimum value. It is important, therefore, to have a ready method for determining the diameter of the wire that will give this minimum resistance. The general method of determining the optimum wire diameter has been discussed in the writer's previous articles. The method is as follows.

Calculate the quantity P from the formula

$$P^2 = LS^2/D^3 \quad .. \quad .. \ (10)$$

in which L is the inductance of the coil in microhenrys, D is the overall diameter of the coil in centimetres and S is a shape factor, namely, $0.186K/L_0^{\frac{1}{2}}$. Then, if f is the frequency (in cycles per second) at which the coil is intended to be used, find the value of f/P^2. If this turns out to be less than 10^4, the optimum diameter d of the wire in millimetres is given by

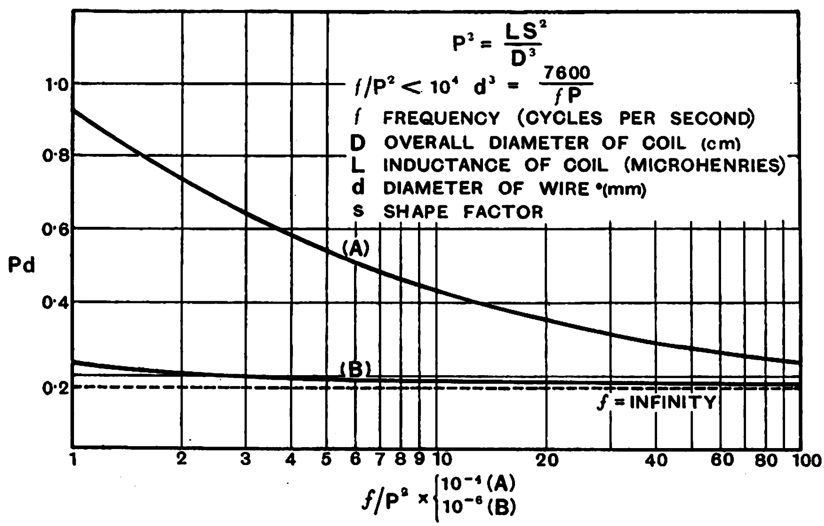
$$d^3 = 7600/fP \quad .. \quad .. \ (11)$$

If f/P^2 is greater than 10^8,

$$d = 0.165/P \quad .. \quad .. \ (12)$$

while for intermediate values of f/P^2, Pd is read off from the accompanying chart.

Values of S for single layer toroids are



For values of S see Tables II and V.

given in Tables II and V. For multi-layer toroids these values should be multiplied by

$$\{1 + \tfrac{1}{3}(1 - 1/m^2)\}^{\frac{1}{2}}.$$

As to whether to employ single or multi-layer coils depends upon the above calculation of optimum diameter. If it turns out that the single layer system can be wound with the requisite diameter, use the single layer system. It should also be used (but not with the optimum diameter) if the optimum diameter is not more than, say, 50 per cent. greater than the available diameter. There is some advantage in using a double layer winding provided that the turns of the second layer are wound in the opposite direction (but still inductively) round the toroid. This system is absolutely astatic, the stray field due to a single layer winding being equivalent to that due to a single loop. It should be noted, however, that such a double winding is liable to have a large self-capacity, so that the complete astaticism may be too dearly bought.

5. Best Shape of Toroid.

Following the method outlined for solenoids in the previous articles we can determine a best shape of the toroid under certain initial assumptions. Probably the most convenient is that the various shapes shall be equally compact. If we measure compactness by the smallness of the area of the bounding cylinder of the toroid we obtain (for high frequencies) the figures given in Tables II and VI for the relative resistances of various shapes when the various toroids are of equal inductance and are each wound with the optimum diameter of wire. The Tables correspond to that given as Table X(B) for solenoids in the writer's *E. W. & W. E.* article for July, 1926, and the figures are directly comparable. Since a single layer solenoid just big enough to envelop the toroid is equally compact, the values for such solenoids are also given in the Tables. It is seen that the single layer solenoid has a resistance which is very considerably less than that of the toroid, and we can summarise the result of the comparison by stating that the H.F. resistance of the best possible toroid is more than twice as great as that of an equally compact single layer solenoid of the same inductance. This, then, represents the price that has to be paid for the astatic property of the toroid.

The Transmission Unit and its Application to Radio Measurements.

By J. F. Herd, A.M.I.E.E.

THE increasing association of wire-cum-wireless to provide complete channels of communication—of which simultaneous and remote broadcasting and the Transatlantic telephony systems form ready examples—serves as a reminder that there is much in common in the technique of measurement in both links of the chain. In particular it may not be out of place to bring before British wireless readers a unit of measurement which is now regularly employed in telephony and which is also applicable to many radio measurements. This is the transmission unit of telephonic practice, which is now standardised in both Britain and America and in several other countries. The unit is no doubt familiar by name to readers of American and of some British wireless literatnre ; the purpose of this article is briefly to explain the unit and describe some of its applications to radio measurements.

The Transmission Unit—Definition.

Fundamentally the transmission unit (usually abbreviated to T.U.) is the logarithmic ratio of two powers (*e.g.*, at two different points in a system, expressing the loss or gain existing between the points).

If we write

$$N_{\text{units}} = \log_{10} P_1/P_2 \quad .. \quad (1)$$

it is clear that this can also be written

$$N = \frac{\log P_1/P_2}{\log 10} \text{ or } P_1/P_2 = 10^N \quad .. \quad (2)$$

Log 10 then becomes the unit of the system, that is one unit will exist when $P_1/P_2 = 10$.

As this ratio was considered too large to form a single unit, the unit actually used was such as to make the ratio ($P_1/P_2 = 10$) to be 10 T.U. so that

$$N_{\text{T.U.}} = 10 \log_{10} P_1/P_2 \quad .. \quad (3)$$

Corresponding to (2)

$$N_{\text{T.U.}} = \frac{\log P_1/P_2}{\log 10^{0.1}} \text{ or } P_1/P_2 = 10^{N/10} \quad .. \quad (4)$$

Log $10^{0.1}$ thus becomes the transmission unit, and 1 T.U. will exist when $P_1/P_2 = \log 10^{0.1}$, *i.e.*, when $P_1/P_2 = 1.259$.

It has been suggested that out of compliment to the memory of Graham Bell, the greater unit described (*i.e.*, such that $N = \log_{10} P_1/P_2$) should be called the Bel, while its sub-multiple, the T.U. (such that $N = 10 \log_{10} P_1/P_2$), should be called the Decibel. These names are not yet, however, in general acceptance, and the so-called Decibel is still under the general name of T.U.

TABLE 1.

	A.		B.		
T.U.	Power Ratio.	Current or Voltage Ratio.	Ratio, Power, Current or Voltage	T.U. for Power Ratio.	T.U. for Current or Voltage Ratio.
1	1.259	1.122	1	0	0
2	1.585	1.259	2	3.010	6.020
3	1.995	1.412	3	4.771	9.542
4	2.512	1.585	4	6.021	12.042
5	3.162	1.778	5	6.990	13.980
6	3.981	1.995	6	7.782	15.564
7	5.012	2.239	7	8.451	16.902
8	6.310	2.512	8	9.031	18.062
9	7.943	2.818	9	9.542	19.084
10	10.0	3.162	10	10.0	20.0
20	100	10.0	20	13.010	26.02
30	1,000	31.62	30	14.771	29.542
40	10,000	100	40	16.021	32.042
50	100,000	316.2	50	16.990	33.980
60	1,000,000	1,000	100	20.0	40.0
—	—	—	1,000	30.0	60.0

Use of Current or Voltage Ratios.

The use of a power ratio (instead of a current or voltage ratio) in defining the fundamental unit is justified especially in

telephonic practice where the impedances may not be equal and where I or V ratios alone would be inadequate. In the case of the wire-cum-wireless chain, this would be especially so in comparing the wire and wireless levels, where comparison of, say, current levels might be meaningless.

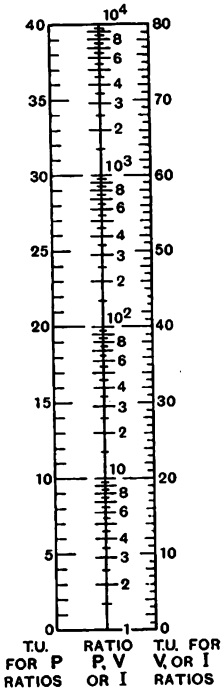


Fig. 1.—
T.U. Conversion Scales.

At the same time, the definition in terms of power does not interfere with the use of current or voltage ratios, where these are associated with equal impedances. In this case, since the currents (or voltages) are proportional to the square roots of the powers, it is merely necessary to use twice as large a constant in computing the T.U. from the current or voltage ratio, *i.e.*,

$$\left.\begin{aligned} N_{\text{T.U.}} &= 20 \log_{10}\frac{I_1}{I_2}, \text{ or } \frac{I_1}{I_2} = 10^{N/20} \\ \text{and} \quad & \\ N_{\text{T.U.}} &= 20 \log_{10}\frac{V_1}{V_2}, \text{ or } \frac{V_1}{V_2} = 10^{N/20} \end{aligned}\right\} \quad (5)$$

The value of transmission units corresponding to known ratios of power, voltage or current is, of course, readily calculable from a table of common logarithms, or by slide rule. Table 1 may, however, help readily to visualise these values, while the scales of Fig. 1 give a convenient means of conversion to sufficient accuracy for most practical purposes.

Advantage of Logarithmic Ratio.

The advantage of a logarithmic ratio is obvious in that it permits addition and subtraction instead of multiplication and division. This is frequently of great convenience in considering a system made up of gains and losses, and in arriving at a comparison of the net result. Additionally in comparing values which are very different in magnitude, the logarithmic ratio gives a much more convenient figure to handle, *e.g.*, in expressing the increase due to a high-gain amplifier (which may easily run into tens of thousands), or in illustrating the cut-off effect of a filter. An example of the latter is given in Fig. 2, taken from Col. A. G. Lee's chairman's address to the Wireless Section I.E.E.*

Other Logarithmic Ratios in Use.

Even in those telephone administrations where the T.U. is not in use, another logarithmic ratio still prevails. This is called the Napier or Neper, and is expressed

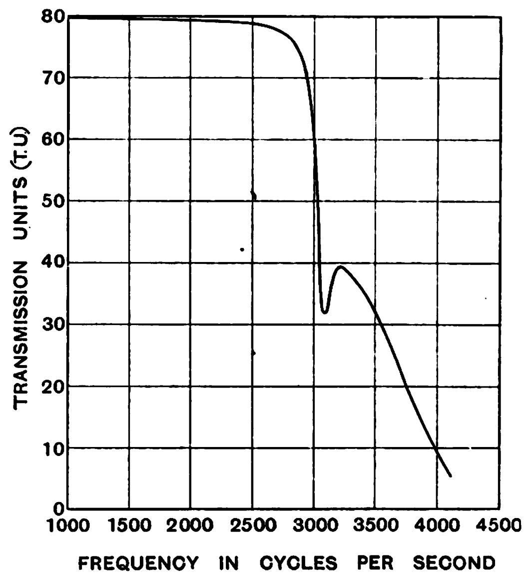


Fig. 2.—*Frequency characteristic of audio-frequency low-pass filter, Transatlantic telephony receiver.*

in terms of the natural or Naperian logarithm of current ratios, *i.e.*,

$$N_{\text{Napiers}} = \log_e I_1/I_2 \quad \ldots \quad \ldots \quad (6)$$

This unit is also used in wireless practice in those countries where it is in force.†

In this case, if power ratios be used,

* *J.I.E.E.*, Vol. 66, p. 12, 1928.

† *C.f.* "Les Filtres Electriques," P. David, Gauthier-Villars et Cie, Paris, 1926.

instead of current ratios,

$$N_{\text{Napiers}} = \tfrac{1}{2} \log_e P_1/P_2 \quad .. \quad (7)$$

Since $\log_{10} N = 2.3026 \log_e N$ it follows that 1 Bel = 1.15 Napiers, and that 1 T.U. = 0.115 Napier or 1.15 decinapiers, or that 1 Napier = 8.686 T.U.

The relative merits of the two systems was the subject of some controversy in *The Electrician* a few years ago when the T.U. was first proposed §, but since the English and American literature is more likely to contain references to the T.U., only this system need be further considered.

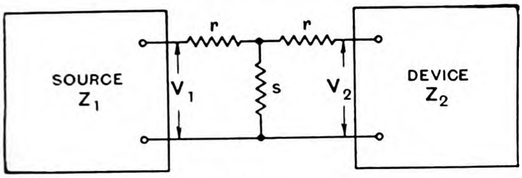


Fig. 3.

Prior to the introduction of the T.U. the unit of telephonic measurement was the "Standard Mile at 800 cycles." In the course of the development of telephone technique, this unit was effectively shorn of its physical significance and came to exist rather as a logarithmic ratio, in the same way as the T.U. and of very nearly the same value. Relative figures are, for the British Specification 1 T.U. = 1.088, 800-cycle miles, and for the American 1 T.U. = 1.056 miles. This calls for mention because non-reactive attenuation boxes are still to be found calibrated in miles.

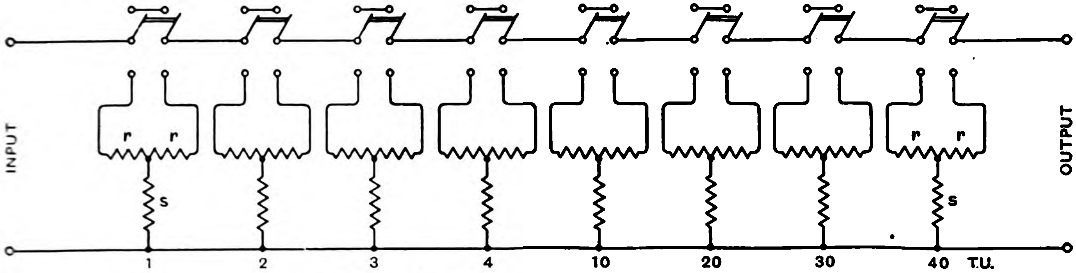


Fig. 4—110 *T.U. Attenuation Box, T-Type.*

Reasons for Choice of T.U.

The reasons for using a power (rather than a current or voltage) ratio and for the size of the T.U. have been very fully dealt with by R. V. L. Hartley in "Electrical Communication,"‡ and need only be referred to very briefly.

The T.U., although a power ratio, is not necessarily the input/output power ratio ordinarily used to define the efficiency of a machine, but it may be the ratio of any two powers whatsoever, according to the circumstances. It may be the efficiency of an instrument or system compared to some fixed reference, the relative powers at two points in the system (as in the case of the powers in a transmitting and receiving aerial) or it may be power in the form of ether waves compared to power in the form of currents in a wire.

Power measurement is of first importance in engineering. Current ratios as a measure of transmission demand knowledge of the impedances involved, and, if this is known, no more measurements are required to give the necessary information about the powers than about the currents. If it is not known the same steps as are required in measuring power must be taken before a knowledge of current ratios has any significance.

The facility with which the T.U., defined on a power basis, can be used in the case of current (or voltage) ratios with equal impedances has already been pointed out.

As regards the size of the unit, from the point of view of a logarithmic base, 10 or ϵ is naturally suggested, or, if these be considered too large for the ratio to be encountered in practice, a suitable sub-multiple is obviously indicated. The T.U., as chosen, has the merit of representing about the least difference in loudness that can be detected by the ear without special training. This makes it of more convenient

§ *The Electrician*, Vol. 94, 1925.

‡ Vol. 3, No. 1, July 1924.

magnitude than either log 10 or log ϵ, while its closeness to the previous "800-cycle mile" involves little change in the case of administrations hitherto using that

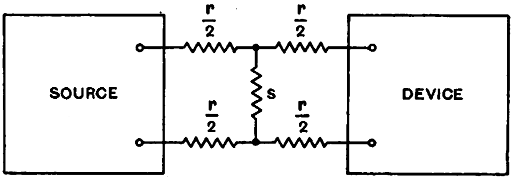


Fig. 5.

unit. At the same time it is, by definition, capable of wider application and can be used in many cases where a statement of miles would be meaningless and could only be employed to denote a ratio. This is particularly the case in the application of the unit to wireless measurements.

T.U. Attenuation Networks.

The practical use of the T.U. in actual measurement is greatly facilitated by a suitable type of calibrated attenuation box. Such networks, calibrated in "standard miles," are of some years standing in telephone practice, but now, calibrated in T.U., form a very useful accessory permitting the employment of the newer and more useful unit.

This type of box employs a non-reactive network of the general type shown in its simplest form in Fig. 3. This will readily be recognised as a frequent practical case, where the measured output from a source has to be reduced by some known amount before application to the device to be operated. (The Americans use the expressive term "sink" as a generic description of such a device.)

Working in terms of attenuation of the source voltage, V_1, the ratio V_1/V_2 can be written in the form

$$\frac{V_1}{V_2} = \frac{X(r + Z_2)}{aZ_2} \quad \ldots \quad \ldots \quad (8)$$

where X is the impedance of the network to which the output terminals of the source are connected, while a is the joint impedance of s, Z_2 and the right hand r.

Various values of r and s can be so chosen that the impedance X remains constant for all values of V_1/V_2, that is for all values of attenuation. It can further be arranged that $Z_2 = X$, that is, the impedance looked into from the source terminals remains constant and equal to the characteristic impedance of the device to be operated. (Generally speaking, also, there will be the tendency for the impedances Z_1 and Z_2 to be matched, this being especially so in telephone practice and in the technique of linking line and radio channels.)

When $X = Z_2$,

$$\frac{V_1}{V_2} = \frac{r + s + Z_2}{s} \quad \ldots \quad (9)$$

from which it follows that

$$r = Z_2\left(\frac{K - 1}{K + 1}\right) = Z_2\left(\frac{1 - R}{1 + R}\right) \quad \ldots \quad (10)$$

and $$s = 2Z_2\left(\frac{K}{K^2 - 1}\right) = 2Z_2\left(\frac{R}{1 - R^2}\right) \quad (11)$$

where

$$K = \frac{V_1}{V_2} \text{ and } R = \frac{1}{K} = \frac{V_2}{V_1}$$

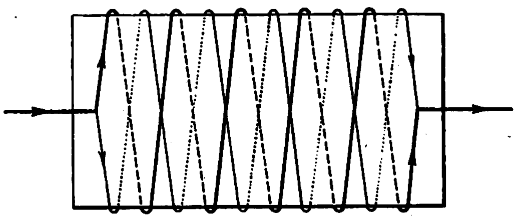


Fig. 6.—*Ayrton-Perry Non-reactive Winding.*

Since V_1 and V_2 are associated with equal impedances, viz., X and Z_2, the ratio V_1/V_2 can be expressed directly in T.U., in accordance with the relations of equation (5).

The resistances r, r, and s can obviously be made adjustable so as to give variable and controllable attenuation calibrated directly in T.U. Such boxes are of regular commercial make, and are a common adjunct of telephonic measurements, while their use at moderate radio frequencies has also been described. The resistance values may be controlled in decade steps, the three resistances being varied by one movement according to the attenuation desired.

A less expensive and more frequently encountered type of box is shown in Fig. 4. Each section of the network introduces a

definite attenuation (in T.U.) and the introduction of the various sections is effected by means of two-way keys of familiar pattern. The calibration of such a box is, of course, only true when it is used in association with the characteristic impedance for which it is designed, and which

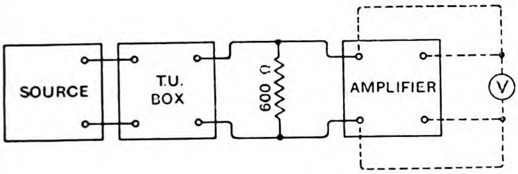


Fig. 7.

satisfies the conditions outlined above. Normally they are made for use with impedances of 600 ohms or of 6,000 ohms, the former being the more usual type. The resistance values (maker's figures) of a T-type network for use with a 600 ohms impedance are shown in Table 2. It will be

TABLE 2.

T.U.	*r* ohms.	*s* ohms.
1	34.5	5,201
2	68.8	2,583
3	102.6	1,703
4	135.8	1,258
10	311.6	421.6
20	490.9	121.2
30	563.2	37.99
40	588.1	12.00

Resistance values of T-type network for 600 ohms impedance.

seen that with the different sections proportioned in accordance with the above reasoning, the attenuation values afforded by each section are additive to give a total of 110 T.U. by steps of 1 T.U.

Boxes are also made to give H-type networks, of the form shown in Fig. 5, both by decade adjustment and by switch adjustment as mentioned for the T-type network.

The resistance units of these boxes are wound in the Ayrton-Perry non-reactive winding, shown schematically in Fig. 6, on flat cards of bakelite or like material. In addition to their obvious uses at telephonic frequencies, their employment at radio frequencies up to at least 50 or 60 k.c., has been described, both in connection with carrier-frequency systems,* and also in connection with field strength measurements on theTransatlantic telephone system.†

It should also be noted that a potentiometer can be divided off or calibrated in terms of transmission units, provided that the resistance of the output portion (and therefore of the whole potentiometer) is not altered by movement of its tapping point. This will be true if the device joined across the output portion takes no current, as, for example, when the potentiometer is used as the gain control feeding into a negative grid. In this case potentiometric adjustment of amplifier gain, calibrated directly in T.U., may be of great advantage.

Typical Uses of T.U. Boxes.

A suitable method of using the T.U. box for a typical and frequent measurement is given in Fig. 7, to measure the gain of the amplifier shown. If the amplifier is not

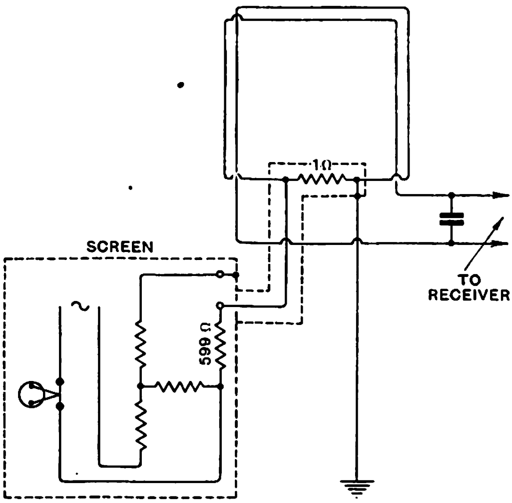


Fig. 8.

already of 600 ohms input impedance, it must be so terminated as shown in the figure. With no attenuation in the T.U. box a thermionic voltmeter, joined across

* Affel and O'Leary. *Trans. Amer. I.E.E.* XLVI, p. 504, 1927.

† England, *Proc. I.R.E.*, II, p. 26, 1923, also Bown, England and Friis, *Proc. I.R.E.*, II, p. 115, 1923.

the 600 ohms terminating resistance, can be used to measure the voltage applied to the input terminals of the amplifier. Attenuation can then be introduced, the voltmeter transferred to the output terminals and the attenuation adjusted, until the voltmeter reads the same as it did on the input terminals. Variations in detail of the method will no doubt occur to the user.

The general method of applying the T.U. box for adjustment of voltage injection in field strength measurements is illustrated in Fig. 8. This is typical of the methods used in the extended series of measurements which preceded the inauguration of the Transatlantic system. The measured output from the oscillator is fed through the T.U. box, terminated on $599 + 1$ ohms. The box is adjusted to the degree required for signal comparison, when the voltage across the 1 ohm in the middle of the frame aerial can be calculated.

Book Reviews.

HOCHFREQUENZ-MESSTECHNIK (High-frequency Measurements). By August Hund, pp. xix. + 526, with 287 Figs. J. Springer, Berlin. 39s.

This is the second edition of this book; the first appeared in 1922. Although the book is written in German, the author has resided for some years in the States and is thus familiar with American methods. It hardly need be said that the subject is dealt with very thoroughly. The theory and practice of all the various classes of high-frequency measurement are described and discussed in twenty-nine chapters, but the author goes so fully into the theory of the phenomena which are to be the object of the measurement that much of the book would better be described as a text-book of high-frequency currents. The formulæ which are to be actually employed in any measurement are printed in heavy type, and special care is taken to indicate the units in which each term is expressed. Short sections dealing with damped oscillators and with Poulsen arc generators are retained because these are still employed in special investigations although no longer a part of ordinary radio work. Modern methods of measuring the strength of the received electric and magnetic fields are described and discussed. Special attention has been given to the theory of long horizontal aerials of the Beverage type, to filter systems with numerical examples and to piezo-electric generators and resonators. The book can be unreservedly recommended to any serious worker in the subject of high-frequency currents who has the necessary knowledge of German.

MATHEMATICS FOR ENGINEERS—PART I. By W. N. Rose, pp. xiv. + 524, with 257 Figs. Chapman & Hall.

The fact that this is the seventh edition of a book first published in 1918 speaks for itself. It obviously meets a need and its appeal is easily understood, for it presupposes very little mathematical knowledge, explains every step very fully and gives a large number of worked numerical examples. Its twelve chapters are entitled: Aids to Calculation; Equations; Mensuration; Introduction to Graphs; Further Algebra; Plane Trigonometry; Areas of Irregular Curved Figures; Calculation of Earthwork Volumes; The Plotting of Difficult Curve Equations; The Determination of Laws; The Construction of Practical Charts; Various Algebraic Processes. The examples consist largely of the application of the mathematical formulæ to problems occurring in various branches of engineering. It is a book that we can recommend to anyone wishing to lay a thorough foundation of practical mathematics.

WIRELESS OBSERVATIONS DURING THE ECLIPSE OF THE SUN, 29TH JUNE, 1927 (being Radio Research Board Special Report). No. 7, pp.25. H.M. Stationery Office. 1s. 3d.

This is a collection of the results obtained in the tests carried out under the supervision of the Board, and also in some experiments made at Liverpool University under the direction of Prof. Marchant. Most of these results have already been published in some form or other, but it is very convenient to have them collected in this form. The long-wave section was prepared by Dr. Hollingworth, the medium-wave section by Prof. Appleton, and the section dealing with direction-finding by Dr. Smith-Rose. Signals from St. Assize ($\lambda = 14,350$ metres) measured at Slough, Aberdeen and Exeter all showed marked effects similar to the preliminary phenomena of a sunset. It is interesting to note that the path from St. Assize to Slough lay entirely outside the totality band and yet the effects were very marked. A large number of measurements were made at various points on the signals sent out from several B.B.C. stations (300 to 500 metres). They indicated a large increase in the downcoming ray, the reasons for which are discussed in the Report. The direction-finding tests indicated a temporary return to night conditions. At Liverpool the signal from Stavanger rose to nearly twice its normal night strength when totality was about midway between the stations. The large amount of interesting data in this Report shows that although the eclipse was generally regarded as a failure, it was certainly a success from a wireless point of view.

G.W.O.H.

Further Notes on the Calibration Permanence and Overall Accuracy of the Series-gap Precision Variable Air Condenser.

By W. H. F. Griffiths, A.M.I.E.E., Mem. I.R.E.

SUMMARY

THIS article is intended to augment the author's previous articles* in which a new precision variable condenser was described. In these articles the author discussed the increased permanence of calibration due to the fact that adjacent dielectric air gaps of this condenser are arranged to be electrically in series and complementary. The increased constancy was shown to be chiefly due to the negligible effect of post-calibration small relative axial displacements of the fixed and moving conductor systems—displacements (amounting to, say, 10 per cent. to 20 per cent. of the total dielectric gap) that would destroy completely the calibration of an ordinary parallel gap condenser.

In the first part of the present article is described a new type of moving plate in which a number of completely insulated sections are employed. By using a multi-sectioned plate of this type the full benefit is obtained from the complementary nature of the adjacent dielectric air gaps by ensuring more complete immunity from that component of calibration inconstancy which is due to small rotation irregularities and to slight post-calibration twisting or tilting of plates. The completeness of the elimination of these errors is discussed to some extent quantitatively.

In the second part final consideration is given to the possible overall accuracy anticipated in a sub-standard wavemeter employing the new variable condenser. In this section are also given various suggested methods of eliminating or reducing errors due to interpolation between calibrated scale points, and of linear interpolation approximations and corrections for use with them.

PART I.

It is not generally realised that the series gap variable air condenser is not entirely immune from capacity changes (for a given angular setting) due to twisting, tilting or uneven sagging of the moving plates subsequent to calibration.

Even assuming perfectly rigid and geometrically permanent fixed plate systems (*i.e.*, absolutely constant *total* dielectric gap distance) the value of a series gap condenser for a given angular setting will not *strictly* be permanent if the planes of the moving plate surfaces are not perfectly parallel to those of the fixed plates at the time of calibration, or do not remain so subsequently, unless a special design of moving plate is adopted.

Since there is a possibility of the dielectric air gaps d_1 and d_2 on either side of the moving plate MP_1 (Fig. 1) varying throughout the area of the latter, the total capacity between fixed and moving plates must be regarded as a number of small capacities in parallel, each of a different capacity as determined by the mean of the gap distances throughout its small area. In Fig. 1 two such parallel sections are shown and the total capacity of such an arrangement will be seen to be

$$C = \frac{(C_1 + C_3)(C_2 + C_4)}{C_1 + C_3 + C_2 + C_4}.$$

the value of which will not remain constant unless

$$C_1 = C_3$$

and

$$C_2 = C_4,$$

for all values of C_1 and C_2.

This condition is, of course, only obtained when the displacement of the moving plate

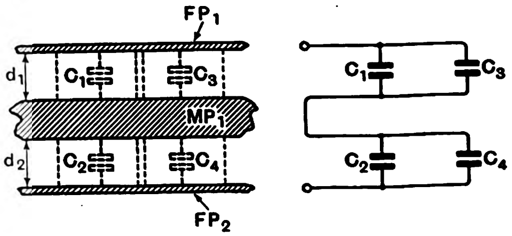


Fig. 1.

is in a direction normal to the planes of the fixed plate surfaces, *i.e.*, a purely axial displacement, such as that due to the wearing

* *E.W. & W.E.*, Jan., Feb. and May, 1928.

of a bearing of a vertical spindle or to " end play " of a horizontal spindle.

In an extreme case of a moving plate tilted so much that two of its edges nearly touch the upper and lower fixed plates as shown in Fig. 2 it is possible to experience a

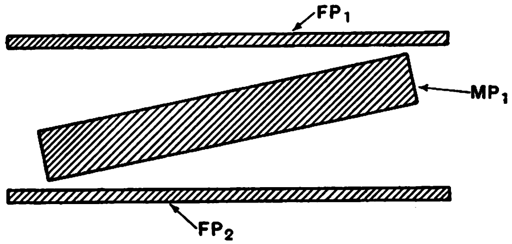


Fig. 2.

great increase of capacity which reaches infinity upon the two fixed plates being touched by the moving plate.

Moreover, if the fixed and moving plate systems are not initially in parallel planes, even purely axial relative displacement will not fulfil the above condition for constancy of calibration.

A Novel Design of Moving Plate.

Although the trouble of tilting or untrue rotation is not very difficult to overcome in variable condensers of precision and is, in any case, rendered less effective by the series gap arrangement, the author has devised a special moving plate which eliminates almost entirely this source of error.

This plate, which is shown in Fig. 3, takes the form of a thick semicircular plate *MP* of glass or other permanent insulating material the surfaces of which are silvered by a reliable process and then copper-plated. By removing fine strips J_1, J_2 of this deposit a number of insulated conducting areas H_1, H_2, H_3, H_4 (coincident on the upper and lower surfaces of the plate) are formed. All the coincident pairs of conducting areas such as H_1, H_3 and H_2, H_4, are joined electrically through the plate. This connection may be made by metal pins by which the plate is pierced before plating, the metal being, of course, deposited on to these pins during the plating process.

Another method of connecting electrically the coincident metallic " islands " is that shown in Fig. 3, the connections being effected by perfect continuity of metal deposit over the slightly rounded edges of the plate or through holes in the inner sections which can be afterwards filled in with metal if desired.

The insulating channels J_1, J_2 must be cut so as to have the least possible effect on the law connecting capacity with angular position of moving system. In the case of the semi-circular linear law plate shown in Fig. 3 it will be seen that the channel J_1, being circular and concentric with the axis of rotation of the plate, does not affect the

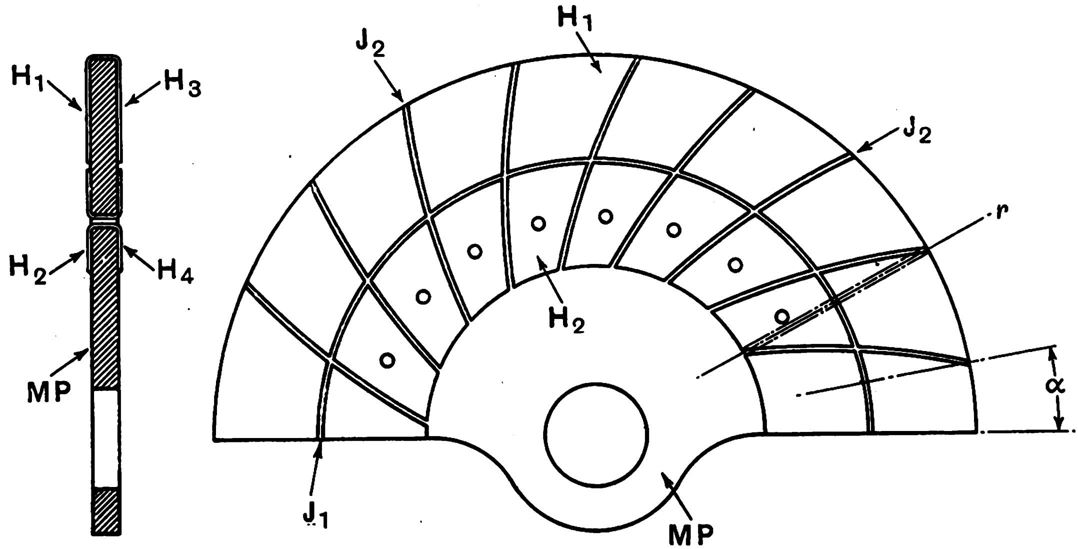


Fig. 3.

law. The channels J_2 are arranged so that the angle at which they intersect any radius is constant so as to have an effect on the law as nearly constant as possible. For this reason also, adjacent J_2 channels are arranged to commence and terminate on the same radius as indicated at r.

Moreover, in order to ensure very close uniformity of law, the J_2 channels are displaced relatively in all the plates of the condenser by varying the angle α by a constant amount in successive plates; the sum of all the displacements being equal to the angular dimension of one island. In other words, for successive plates the whole system of channels is uniformly swung round on the axis of the plate so that, throughout the completed condenser, no J_2 channels are exactly coincident and all are angularly equidistant. The number (and position) of channels which are entering or leaving the radial edges of the fixed plate system is therefore constant throughout the range of the condenser, the effect (on the law) of these channels being in consequence very small indeed.

In order to ensure perfect reliability, the plating thickness as well as the nature of the surface upon which it is to be deposited must be carefully considered. For permanence the plating must be very thin, but this is not an objection from a power factor point of view, for even a 0.0002in. deposit has a resistance not greater than 0.01 Ω per island, corresponding to a power factor (from this cause only) of the order 5×10^{-6} even at frequencies as high as 3×10^7 per second (10 metres).

It is interesting to note that the "skin-depth" for copper at this frequency is safely greater than half this thickness, and is not therefore a limiting factor.

In practice the plating thickness can conveniently be made greater than 0.0002in., and the continuity of deposit ascertained by a resistance measurement of each pair of islands as well as by a microscopic examination of all edges.

This design of plate, which may be used in the condenser as described in the author's previous articles, produces a changed electrical scheme since the moving plate now consists of a number of conductors sufficiently insulated from one another to permit their maintaining the slightly different potentials consequent upon their different positions in the field between the two fixed plates. Thus a number of independent series gap capacities are formed, the whole being joined in parallel by the continuity of the adjacent fixed plates. The four elementary capacities C_1, C_2, C_3 and C_4 of the simple two-area gap previously considered may now be represented as in Fig. 4.

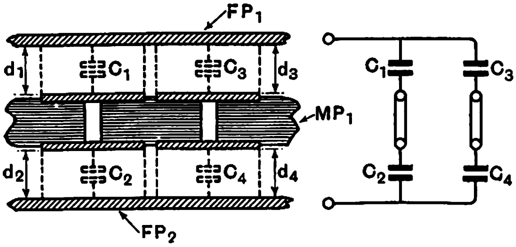


Fig. 4.

The capacity of C_1 and C_2 in series is constant irrespective of changes of position of the moving plate

$$\left(\text{since } C = \frac{C_1 C_2}{C_1 + C_2} \propto \frac{1}{d_1 + d_2}\right)$$

and, that of C_3 and C_4 in series being similarly constant, the sum of $\dfrac{C_1 C_2}{C_1 + C_2}$ and $\dfrac{C_3 C_4}{C_3 + C_4}$ must now be constant, irrespective of any relation between C_1 and C_3 or between C_2 and C_4, *i.e.*, irrespective of a twisting, tilting or uneven sagging of the moving plate (causing differences between d_1 and d_3), as well as of purely axial displacement or "end play."

For this latter statement to be perfectly true it would, of course, be necessary to assume an infinite number of conducting sections, but in practice the gap unevenness is so small that relatively few sections will suffice to bring about the desired permanency.

Another feature which will, from theoretical considerations, militate against absolute constancy is the existence of capacity between adjacent metallic sections of the moving plate. These capacities will, of course, bridge points which will not necessarily be at the same potential if gap irregularities are present, but again, in practice, this contribution to inconstancy is small even for comparatively few sections if these unwanted capacities are kept small, as the potential differences between those

sections which are immediately adjacent will in any case be small.

It will therefore be obvious that in order to obtain the best condition for constancy the capacity between adjacent sections of the moving plate must bear some relation to that between those sections and the fixed plates. The former should, of course, be made smaller than the latter but not at the expense of the linearity of the capacity law by making the insulating channel wide. If 1in. square be taken as the practicable order for the section areas of the moving plate, the most suitable channel width may be selected from the curve (Fig. 5) plotted between intersection capacity and width of channel. This curve is plotted from measurements made when the dielectric gap distances d_1, d_2 between adjacent moving and fixed plate surfaces was 0.045in., the moving plate to fixed plate capacity per section corresponding with this gap dimension being $5\mu\mu F$ approximately.

It is necessary to make such measurements

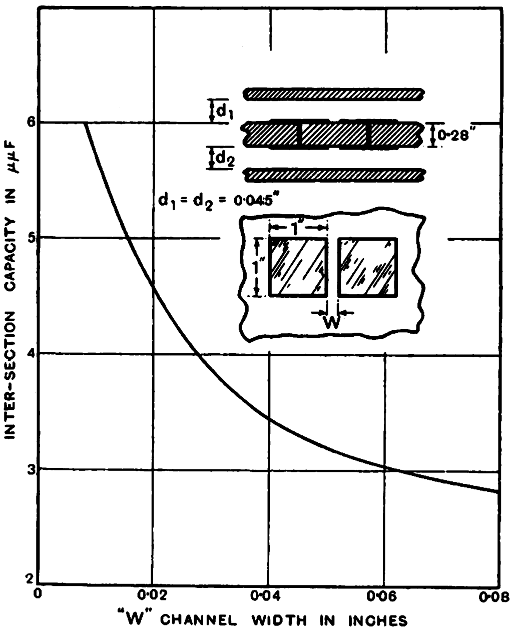


Fig. 5.

with the gap dimension adjusted correctly because this has a bearing upon the capacity between adjacent moving plate sections, owing to the fact that the neighbouring fixed plates intercept a portion of the field between these sections to an extent which naturally increases as the gap diminishes as is shown by the curve of Fig. 6. The capacity measurements of Figs. 5 and 6 were therefore made while the two 1in. square sections were enclosed by a screening plate on either side, which plates, when connected together, formed the third or screen terminal of a three-terminal condenser.

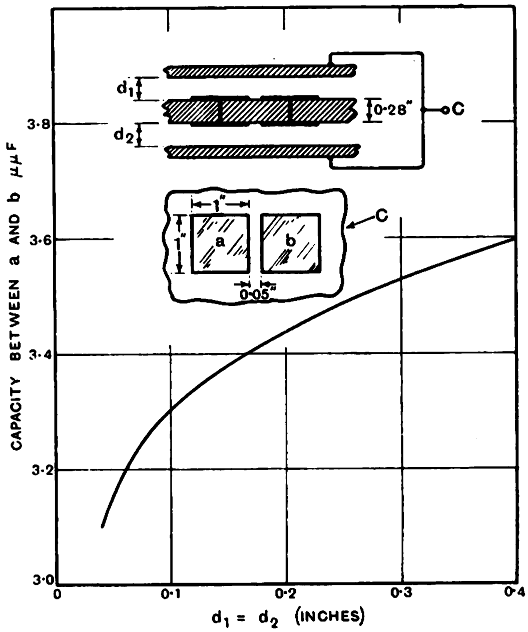


Fig. 6.—*Capacity between a and b with screen plates removed completely* 3.9*F.*

With this screening system earthed the pure intersection capacity between *a* and *b* was then determined independently of that between *a* and *c* and between *b* and *c* by a double capacity bridge method in which earth capacities do not contribute to the capacity being measured.

It will be seen from Fig. 5 that an insulating channel width of about 0.05in. besides being convenient and practicable also gives an intersection capacity appreciably less than $5\mu\mu F$, thus justifying the adoption of section areas of the order originally decided upon.

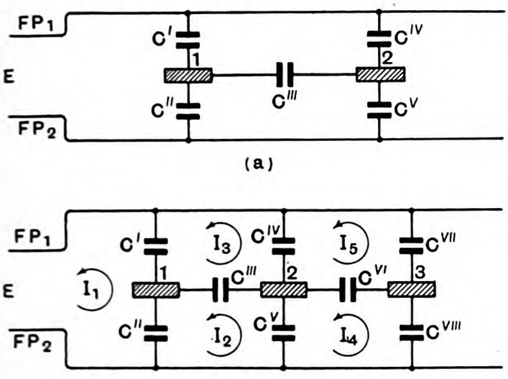
In order to ascertain to what extent this subdivision of moving plate is effective in reducing the change of capacity with an "incline displacement" of the fixed and moving systems, a number of cases have been calculated for strips of moving plate having varying numbers of these unit

section areas of 1in. square, all of which have a main fixed to moving plate capacity of $5\mu\mu$F when the moving plate is adjusted to its normal mid-gap position.

These calculations are made from capacity networks, examples of which are given in Figs. 7a and 7b, for moving plate strips of two and three sections respectively.

In these networks C^i, C^{ii}, C^{iv} C^v, C^{vii} C^{viii}, vary from their normal value of $5\mu\mu$F. according to the post-calibration "incline displacement" of the moving plate—each pair in a complementary manner—if the incline be considered as negligible throughout the length of each section.

The first of these sets of calculations was made for an incline displacement per section of 10 per cent. of the total dielectric air gap from the normal mid position, and as an approximation for the purposes of calculation the incline throughout the length of each section was ignored. Thus of the gap



(a) (b)

Fig. 7.

capacities for a 10 per cent. incline displacement per section in the case of Fig. 7b, C^{iv} and C^v *remain constant*, C^{ii} and C^{vii} *increase* corresponding to a 10 per cent. reduction of normal gap distance and C^i and C^{viii} *decrease* corresponding to a 10 per cent. increase of gap distance.

The resultant capacity C_R after this change has taken place is best determined by adopting Maxwell's theory of networks in which I_1, I_2, I_3, I_4 and I_5 of Fig. 7b are hypothetical cyclic currents. Thus in the case being given as an example five equations can be formed :—

$$\frac{1}{\omega}\left(\frac{1}{C^i}+\frac{1}{C^{ii}}\right)I_1 - \frac{1}{\omega}\left(\frac{1}{C^{ii}}\right)I_2 - \frac{1}{\omega}\left(\frac{1}{C^i}\right)I_3 = E \quad .. \quad (1)$$

$$-\frac{1}{\omega}\left(\frac{1}{C^{ii}}\right)I_1 + \frac{1}{\omega}\left(\frac{1}{C^{ii}}+\frac{1}{C^{iii}}+\frac{1}{C^{v}}\right)I_2 - \frac{1}{\omega}\left(\frac{1}{C^{iii}}\right)I_3 - \frac{1}{\omega}\left(\frac{1}{C^{v}}\right)I_4 = 0 \quad .. \quad (2)$$

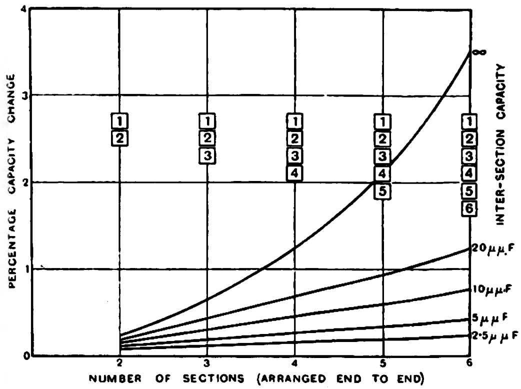


Fig. 8.—1 *inch square sections* (5*F*.) 10 *per cent. displacement per section.*

$$-\frac{1}{\omega}\left(\frac{1}{C^{i}}\right)I_1 - \frac{1}{\omega}\left(\frac{1}{C^{iii}}\right)I_2 + \frac{1}{\omega}\left(\frac{1}{C^{i}}+\frac{1}{C^{ii}}+\frac{1}{C^{iv}}\right)I_3 - \frac{1}{\omega}\left(\frac{1}{C^{iv}}\right)I_5 = 0 \quad (3)$$

$$-\frac{1}{\omega}\left(\frac{1}{C^{v}}\right)I_2 + \frac{1}{\omega}\left(\frac{1}{C^{v}}+\frac{1}{C^{vi}}+\frac{1}{C^{viii}}\right)I_4 - \frac{1}{\omega}\left(\frac{1}{C^{vi}}\right)I_5 = 0 \quad .. \quad (4)$$

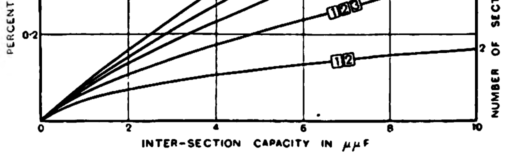


Fig. 9.—1 *inch square sections* (5*F*.) 10 *per cent. displacement per section.*

$$-\frac{1}{\omega}\left(\frac{1}{C^{iv}}\right)I_3 - \frac{1}{\omega}\left(\frac{1}{C^{vi}}\right)I_4 + \frac{1}{\omega}\left(\frac{1}{C^{iv}}+\frac{1}{C^{vi}}+\frac{1}{C^{vii}}\right)I_5 = 0 \quad .. \quad (5)$$

These equations can be simplified by making ωE equal to unity in (1) and by eliminating $\frac{1}{\omega}$ in the remainder, then,

$$C_R = \frac{I_1}{\omega E} = I_1$$

and the equations are therefore solved by the method of determinants for I_1 only.

In the curves of Fig. 8 are given the post-calibration changes in capacity for strips of various numbers of moving plate sections, each of 1in. square area, and arranged end to end as depicted, due to an incline displacement of 10 per cent. per section. Curves for several possible values of inter-

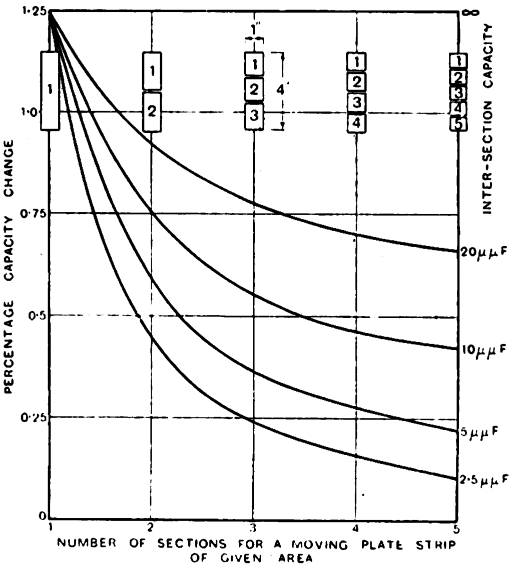


Fig. 10.—30 *per cent plate tilt over* 4 *inches.*

section capacity are given as well as one for infinity intersection capacity which gives, for comparison with the others, the capacity change which would be experienced with a solid moving plate under similar circumstances.

It may at first be thought from the simple consideration of a two-element system that no *great* benefit can be derived from the sub-division of the moving plate—the error in this case with an intersection capacity as low as 2.5$\mu\mu$F being only reduced to one-third. The curves of Fig. 8, however, at once show the marked benefit to be derived

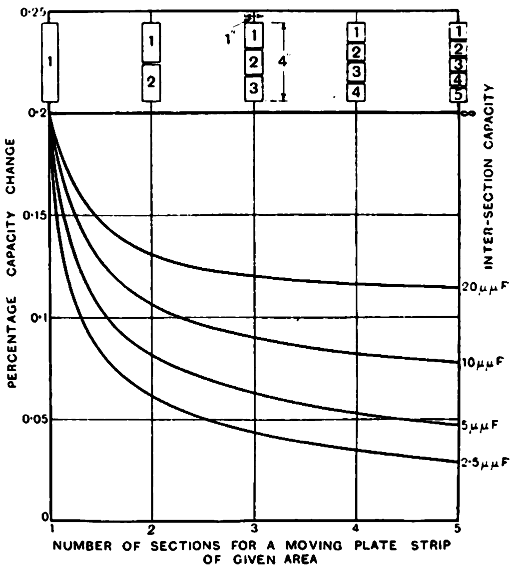


Fig. 11.—15 *per cent. plate tilt over* 4 *inches.*

from the use of a multi-sectioned moving plate when the inter-section capacity is kept low and a large number of sections are considered; the error when six sections are considered being reduced to about 0.06 of that for a solid plate.

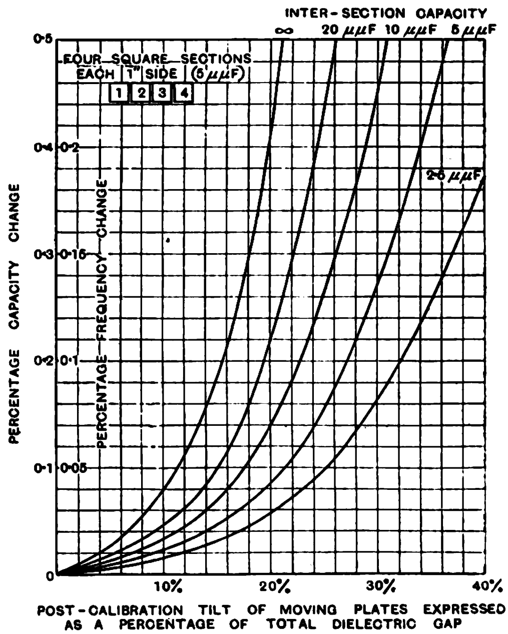


Fig. 12.

Fig. 9 shows these results plotted in a different manner to show the greater benefit derived from keeping the intersection capacity low when many sections are considered.

The curves of Fig. 10 show the reduction of error due to a given post-calibration moving plate tilting in *a given plate area* for various numbers of sub-divisions as depicted on the curve, and for intersection capacities of various values. These curves are for a plate area strip of 4in. by 1in. throughout the length of which an incline of 30 per cent. of the normal gap occurs, the normal moving plate to fixed plate capacity being 5$\mu\mu$F per sq. in. as in all previous curves. The purpose of this family of curves is to show that there is a limiting number of sub-divisions *for a given plate area* beyond which no extra benefit is derived, largely owing to the fact that the fixed to moving plate capacity becomes smaller as the number

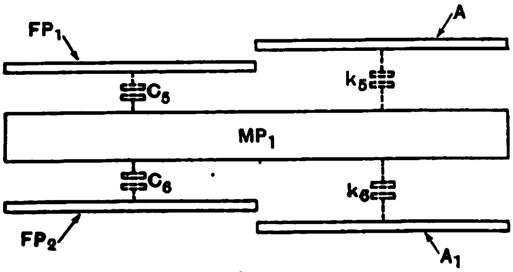


Fig. 13.

of sub-divisions is increased, thus making a given intersection capacity too high for the extra sub-division to be effective.

In Fig. 11 is given a similar family of curves for a total post-calibration incline of plate of only 15 per cent. (half that of Fig. 10) the errors it will be observed are of a much lower order.

The most useful set of curves is, perhaps, that of Fig. 12 for a 4 × 1in. strip of moving plate subdivided into four sections, each having a normal capacity to fixed plate of 5$\mu\mu$F. The capacity error is given for various degrees of post-calibration moving plate tilting—the total tilt being expressed as a percentage of the normal dielectric air gap. Curves are given for various values of intersection capacity—that for infinity capacity being included to show the error that would occur with a solid (unsubdivided) moving plate under similar conditions.

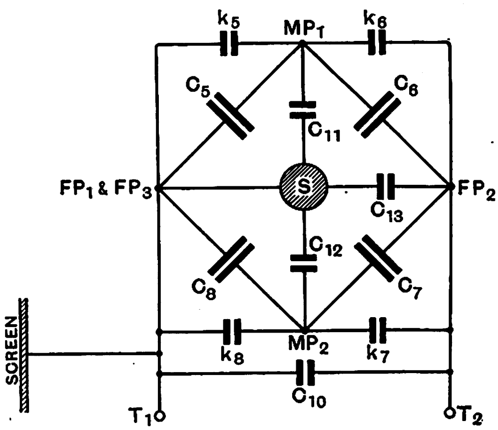


Fig. 14.

A Further Advantage of Using a Multi-sectioned Moving Plate.

The adoption of this multi-sectioned moving plate also removes another minor imperfection, which contributes to the inconstancy of a series gap condenser due to the capacities from MP_1 to the screening plates A and A_1 (Fig. 13) not varying in

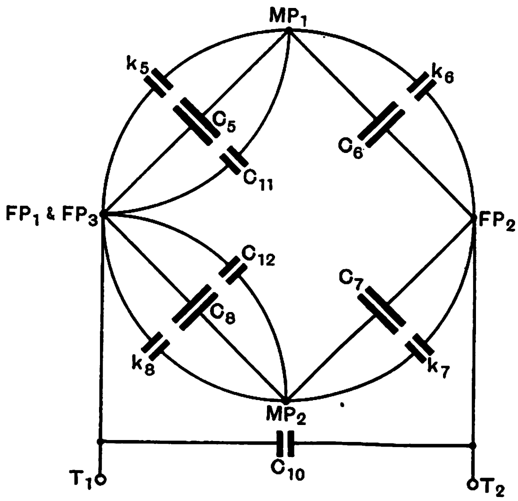


Fig. 15.

the same ratio as those from the same plate to the actual fixed plates FP_1 and FP_2 when an axial relative displacement of fixed and moving plates occurs. The five plates concerned are shown in elevation in Fig. 13, which indicates the moving plate

only half entered between the fixed plates FP_1 and FP_2 corresponding to the 90 deg. scale position.

Fig. 14 shows the complete electrical diagram of one section (three fixed plates and two intermediate conductors or moving

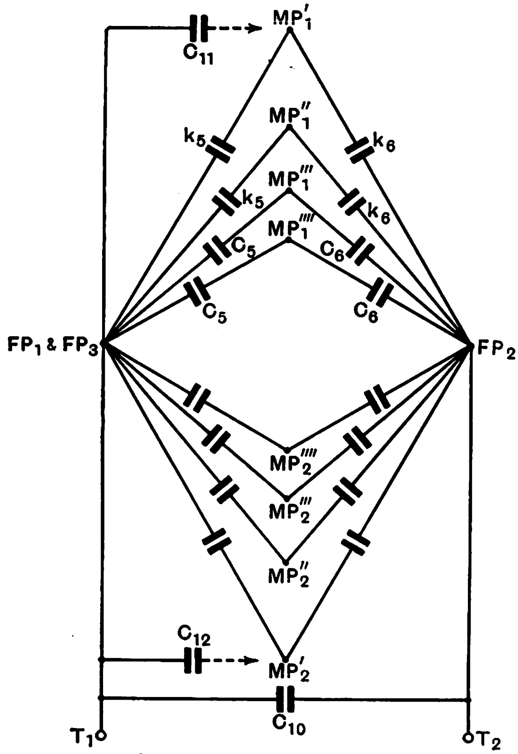


Fig. 16.

plates) of the series gap condenser, showing the gap capacities C_5 and C_6 on either side of the moving plate MP_1 augmented by those, k_5 and k_6, from the same plate to the screening plates which are connected to the appropriate fixed plate systems.

Unfortunately k_5 and k_6 cannot, if the moving plate be solid, be treated separately as a series gap capacity.

$$\frac{k_5k_6}{k_5+k_6} \text{ in parallel with } \frac{C_5C_6}{C_5+C_6}$$

because MP_1 is a potential fixing point common to both circuits. With a given axial displacement, therefore, even though it be in a direction purely normal to the planes of the plate surfaces, the gap capacities k_5 and k_6 are more nearly constant than the larger capacities C_5 and C_6 and therefore assist the spindle capacities C_{11} and C_{12} in tending to oppose the complementary changes in the capacities of the arms of the Wheatstone bridge upon which the whole principle depends. The diagram of Fig. 14 is redrawn in Fig. 15 for simplicity.

With the multi-sectioned moving plate, however, the capacities C_5 and C_6, k_5 and k_6, etc., consist of many insulated pairs of series capacities as shown in Fig. 16, the intermediate conductors MP_1^{i}, MP_1^{ii}, MP_1^{iii} and MP_1^{iiii} of which are not necessarily at the same potential. The resultant capacity of each series pair of capacities will, of course, remain constant and the sum of all the pairs will therefore also be constant for all axial positions of the moving plate, irrespective of the difference of total dielectric gap distance between adjacent fixed plates at various portions of the moving plate surface

$$\left(e.g., \text{ irrespective of the difference between the values of } \frac{C_5C_6}{C_5+C_6} \text{ and } \frac{k_5k_6}{k_5+k_6}\right)$$

The limiting factor of intersection capacity of course applies here as in the case of plate tilting, but it will be found that the limitation is not serious if these parasitic capacities are kept down to the order already given.

(To be Concluded.)

The Attenuation of Wireless Waves Over Towns.

Paper by Messrs. R. H. Barfield, M.Sc., A.M.I.E.E., and G. H. Munro, M.Sc., read before the Wireless Section Institution of Electrical Engineers on 5th December, 1928.

Abstract.

THE present paper is supplementary to a paper on "The Attenuation of Wireless Waves Over Land,"* read before the Wireless Section last year by one of the authors. The previous paper dealt with the effect produced by the open country, while the present paper discusses the attenuation over towns, including the effect of buildings and tuned aerials and other structures.

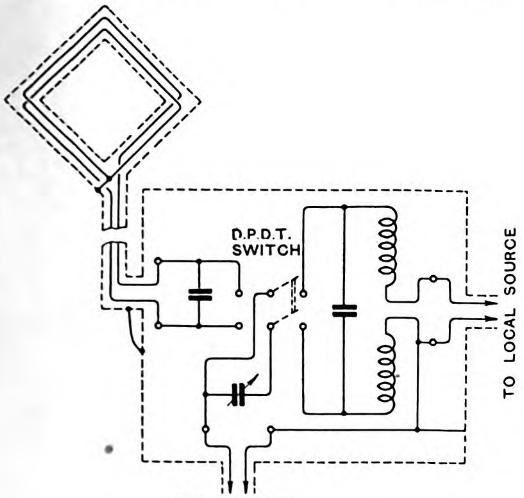


Fig. 1.—*Portable intensity measuring apparatus (dotted lines indicate screening).*

DESCRIPTION OF EXPERIMENTAL WORK.

(1) Measurement of the Polar Curve of 2LO and Construction of a Revised Contour Map.

For measurement of a polar curve at comparatively short distances from the transmitter it was necessary that the apparatus should be convenient for use in crowded town districts and capable of allowing a large number of observations to be made in a day's run. It was therefore designed for use in a motor van with a frame aerial coil on the top, so that the apparatus could remain set up and be brought quickly into use when the van was stopped at a suitable site.

The arrangement of the circuits is shown in Fig. 1.† The frame aerial is of "pancake" type with a screen of aluminium, to serve as a weather protection, as well as to reduce "antenna effect." The centre of the coil is earthed to the screen and to a brass tube passing into the inside of the van, and containing leads to the tuning panel. A standard 7-valve amplifier is used in a screened case, with batteries in another screened box, while a third box contains the detector H.T. battery, series micro-ammeter and shunts. A screened oscillator of measured output supplies a local signal to the dummy circuit having the same constants as the frame aerial.

The method consists in comparing the received signal in the frame aerial with the local signal in the dummy circuit. The strength of the signals is indicated by the deflection of a micro-ammeter in the detector anode circuit. The coil is turned until the deflection due to the received signal produces the same deflection as does the signal from the local source. The strength of the received signal is then $1/\sin\theta$ times that of the local signal, provided that the frame reception follows a cosine law.

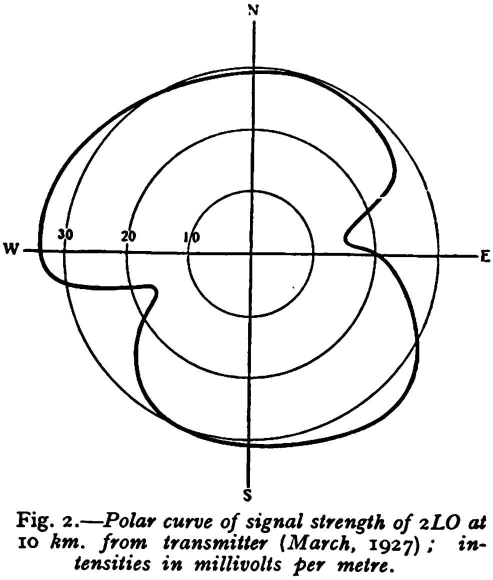


Fig. 2.—*Polar curve of signal strength of 2LO at 10 km. from transmitter (March, 1927); intensities in millivolts per metre.*

Observations were made on sites which were reasonably level and as free as possible from likely sources of error, such as telegraph wires and trees. A final observation was taken on returning to the Research Station after each run and the day's

* *J.I.E.E.*, 1928, Vol. 66, p. 204; Abstract in *E.W. & W.E.*, January, 1928.

† The authors' original figure numbers are adhered to throughout this abstract.

results calculated relative to it. The apparatus was calibrated against a local transmitter.

Polar Curve of 2LO.—Observations were taken on suitable sites approximately on a radius of 10 km. from the transmitter, or, where suitable sites were not available at this distance, on a radius of 15 km. Readings were taken at intervals of not greater than 10 deg.

The resultant polar curve is shown in Fig. 2, due to surface. This may be further evidence of the "negative" surface attenuation effect found by Ratcliff and Barnett in the neighbourhood of the long-wave Daventry station.* On the other hand it may be that the effective height of the aerial is greater than that assumed.

The two mimina in the polar curve are clearly due to the directional characteristics of the aerial, and are no doubt owing to currents induced in the

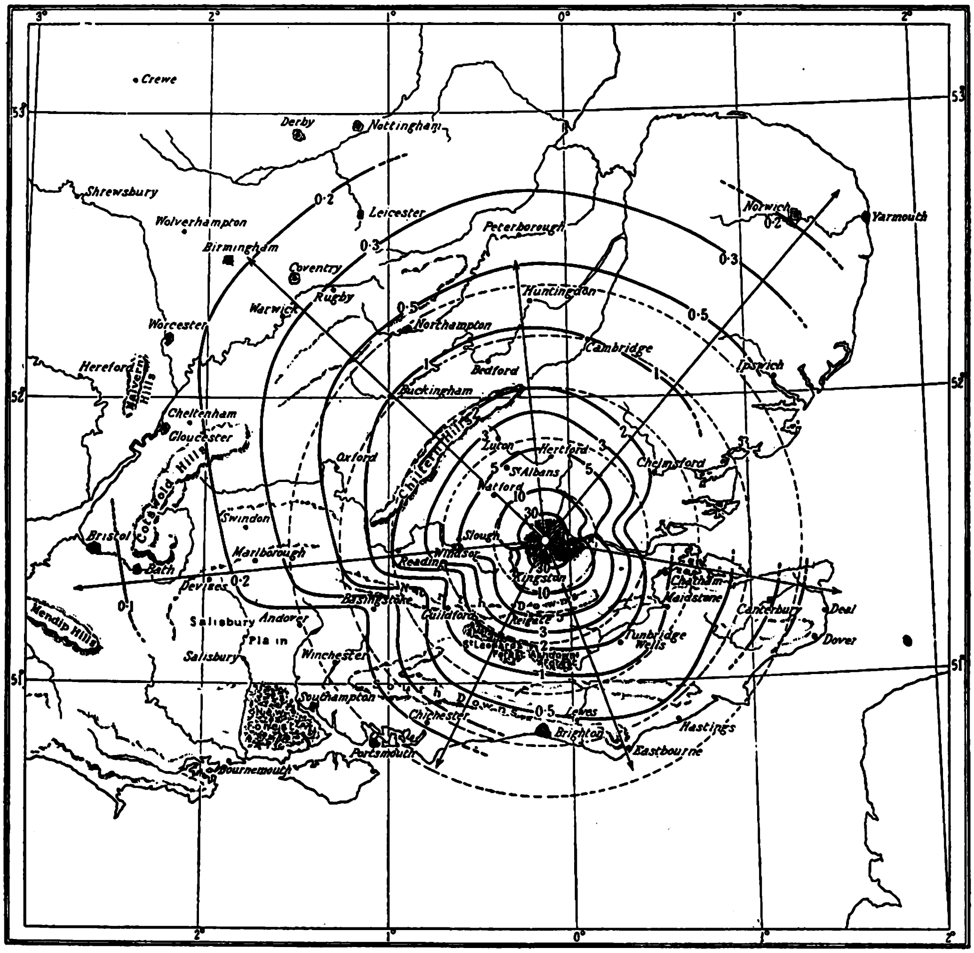


Fig. 3.—*Radio contour map of 2LO; revised survey made March, 1927 (distances from 2LO shown by dotted circles at intervals of 20km.); intensities in millivolts per metre.*

the values being corrected to 10 km. As a check of the sudden dip to the West a series was taken on a radius of 40 km., showing that the change was of the same order at that distance.

The calculated theoretical intensity of 2LO at 10 km.—neglecting surface attenuation—is shown to be 28 mV./m., though a certain amount of doubt arises as to the effective height of the transmitting aerial which is on the top of a large building, and is taken as 30 m. The average value in Fig. 2 is 30 mV./m., suggesting no attenuation two masts. To produce the effect shown in the curve the currents induced in the mast must be of the same order as that in the aerial. This is surprising as the mast height (40 m.) is well below $\frac{1}{4}\lambda$ and therefore well out of resonance.

Revised Survey of 2LO.—This polar curve and the attenuation curves of the previous paper have been used to draw Fig. 3, a contour map of the signal strength of 2LO, which is a revision of that

* *Proc. Camb. Phil. Socy.*, 1926, Vol. 23, p. 288.

previously given. This revision became necessary because the first contour was constructed from observations at intervals of about 50 deg., while there have also been changes to the transmitting aerial which have altered its directional characteristics. The chief difference is the appearance of the crevasses W. S. W. and E. N. E., due almost certainly to the directional properties of the aerial, and corresponding to the minima in the polar curve. These may have existed at the time of the earlier survey remaining undiscovered because these directions were not selected for a tour. Their appearance now does not affect the previous conclusions with regard to the attenuation of waves (due to trees).

(2) Experiments to Determine Change of Attenuation with Wavelength.

The first experiments of this nature were in November, 1926, when measurements of the B.B.C. Strand transmitter were made at Slough and at the N.P.L. on a number of wavelengths in the region of 360 m. The results are in Fig. 4, both showing a rapid fall-off of intensity with decrease of wavelength.

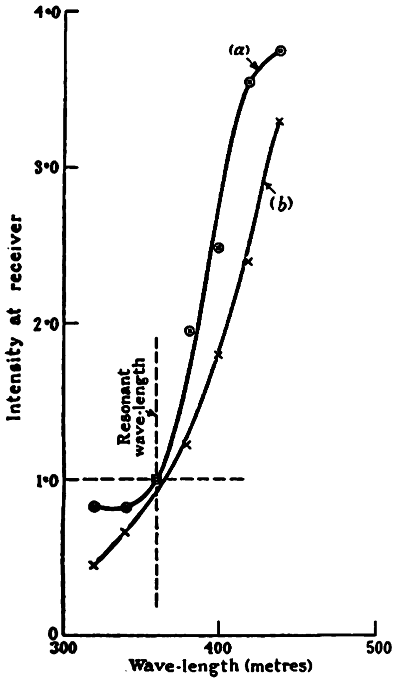


Fig. 4.—*Effect of wavelength change on received intensity. Transmitter: 2LO. Receivers: (a) Slough. (b) Teddington.*

To determine whether this was due to characteristics of the transmitter or to those of the intervening space, experiments were carried out using the N.P.L. transmitter (5HW) which could work over a greater wavelength range.

The experiments were carried out at a number of different sites in different directions from the transmitter. At each site the transmitter wavelength was changed in steps of 20 m. from 440 m. to 260 m. The transmitter was found to have a very marked frequency characteristic of its own. To eliminate this from the results, the measurements have all been expressed in terms of their value in a direction free from houses (viz., the route from N.P.L. to Wimbledon).

Intensity/wavelength curves are given in Fig. 6. In Curve 1 (N.P.L. to Regent's Park) transmission is over five or six miles of open country, then over five or six miles of densely populated town area (Hammersmith, Earl's Court, Paddington). A very rapid decrease of intensity with decrease of wavelength is seen.

For Curve 2 (Kew) the path is over three miles of closely built suburban area, then over the river and about half a mile of open grass. This is also the route for Curve 3 (Willesden), then over seven miles of sparsely populated districts (Gunnersbury, Park Royal, Wembley) with the crowded suburbs of Ealing and Acton on its flanks. Both curves show a marked minimum at between 320 and 340 m. with a marked difference of attenuation on the extreme wavelengths, *i.e.*, about 2 to 1.

Curve 4 (Richmond Park) shows a less marked minimum, with intensity ratios of 1.2 to 1, while in Curve 5 (Ham Common) the dip is again present, but still less marked, while the overall change in attenuation is small and reversed.

In the case of Curve 6 (Streatham Common) the transmission passes over the outskirts of Kingston, open country South of Wimbledon Common, and over the crowded districts of Merton, South Wimbledon and Tooting. The curve is irregular, without a dip but with a sudden drop of intensity at 300 m. The ratio on the extreme wavelengths is again about 2 to 1.

Curves 8, 9 and 10 are for Hampton Barracks, Hampton and Ditton Park respectively. These transmissions do not pass over any area of buildings and show no sign of dip and no great change in attenuation.

From these it is concluded that when transmission is wholly over a dense town area there is a very marked increase of attenuation with frequency. In the case of the Regent's Park site the change in intensity over ten miles, of which only four are in town area, is approximately 9 to 1, corresponding to a variation proportional to fourth or fifth power. Over a similar distance to Ditton Park there is a change of 2 to 1, corresponding to a law embodying a power between the first and second, which is in accordance with Sommerfeld's theory.

Another effect is that over well-populated suburban areas there is selective absorption between 320 and 350 m. It seems that this can only be caused by the number of receiving aerials all tuned to the 360 m. of 2LO. This selective absorption is a maximum when the area traversed contains the maximum number of houses, in the cases of Kew and Willesden and decreases in importance in other curves. The result for Streatham is unexpected, for, although the last part of the route is over dense residential districts, no selective absorption is recorded.

It is concluded that when transmission is confined to "town" areas only, consisting of offices,

large buildings and residential districts without gardens, there is an increase of attenuation with frequency following approximately a fifth power law. Over suburban areas there is marked selective absorption which is a maximum on a wavelength just below the tuned wavelength. In the case of 2LO to Slough (Fig. 4) there are indications that the steep attenuation curve is combined with the curve of selective absorption.

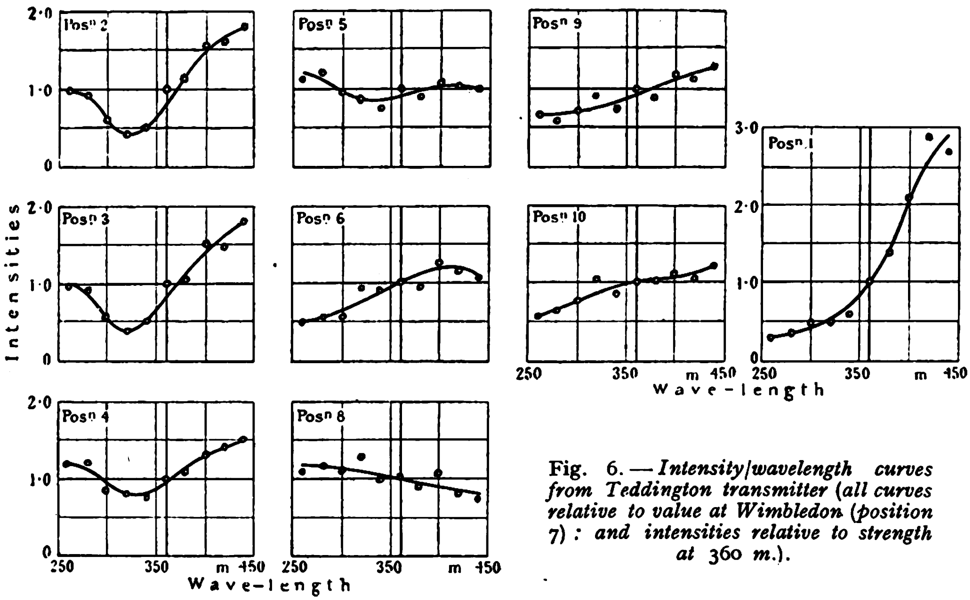


Fig. 6.—*Intensity/wavelength curves from Teddington transmitter (all curves relative to value at Wimbledon (position 7): and intensities relative to strength at* 360 *m.*).

THEORETICAL DISCUSSION OF RESULTS.

Considering the rate of change of attenuation with wavelength over town areas, the surface may be considered as being made up of :—

(1) Vertical conductors, earthed and unearthed.

(2) Horizontal conductors.

(3) Vertical and horizontal closed metallic loops.

(4) Dielectrics.

Sommerfeld's expression for surface attenuation is then considered and converted to a form which makes it applicable to any kind of surface.

Vertical Conductors.—A further expression is then derived for the energy absorbed by a distribution of N vertical earthed conductors per unit area, and it is shown that the intensity would vary as the fifth power of the wavelength which is in accordance with the experiments. A value for N is also traced, suggesting that it would have to be of the order of 100,000 per km.^{2}, corresponding to a mass of conductors spaced about 10ft. apart. This is undoubtedly too close for the average state of affairs, but the calculation is based on very rough estimates. It seems probable that absorption by short vertical conductors would account for an appreciable portion of the absorption.

Horizontal Conductors.—It is impossible to estimate the various constants, but it is probable that long lengths of such conductor would rather assist propagation.

Vertical Loops.—The effect will be chiefly in the vertical sides of the loops, as for vertical conductors.

Horizontal Loops.—Absorption effect theoretically zero.

Dielectric Losses.—The energy absorbed by dielectric losses in stones, plaster, etc., is very difficult to estimate. An approximate calculation is given, however, showing that the attenuation will vary inversely as λ^5.

It is thus concluded that vertical conductors, such as pipes, steel frames of buildings, lamp-posts, electric wiring, etc., give losses following a frequency law of the correct nature, while dielectric losses might also account for it if of a certain nature and sufficiently intense. No account has here been taken of receiving aerials which would be small and inefficient in such localities.

Selective Absorption.—There are two ways in which a mass of tuned receiving aerials might influence the field strength at a point remote from them: (1) by absorbing energy from the waves as they pass over, and (2) by re-radiating waves which interfere with the main waves at the point under consideration.

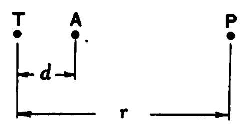


Fig. 7.—*Diagram to illustrate theory of aerial shadow effect.*

(1) *Energy absorbed by Mass of Tuned Aerials.*—It is shown that with 100 aerials per km.^{2} corresponding to 1 every 100 m. in parallel streets of houses 100 m. apart, the attenuation would be about 0.75. That is, at 10 km. away from the transmitter the field-strength would be 0.75 of its

normal value so long as the receiving aerials were tuned to the transmitter. For wavelengths above and below this value the signal strength would be greater approaching the normal value. Hence this type of absorption will give a minimum signal strength at the resonant wavelength, while the density of aerials which actually occurs in suburbs would produce an appreciable effect.

(2) *Shadow Effect of Mass of Receiving Aerials.*— Assume a collection of N receiving aerials of broadcasting type all tuned to the same frequency λ_0 with average height h and resistance R. Considering first the effect of a single aerial situated at a distance d from the transmitter (Fig. 7), the resultant intensity E of the electric field at P is derived as

$$E = K\sqrt{\left[1 - \frac{2A}{\lambda Z_A}\sin\phi + \left(\frac{A}{\lambda Z_A}\right)^2\right]}$$

where $A = \dfrac{4\pi x h^2{}_A}{cd(x-d)}$; $\phi = \arc\tan\dfrac{\omega L - 1/(\omega c)}{R}$

and $$K = \frac{4\pi I_T h_T}{c\lambda},$$

while c is velocity, and I_T and h_T refer to the transmitting aerial.

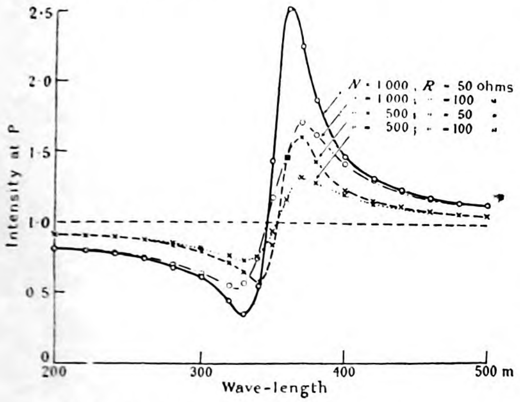


Fig. 8.—*Aerial shadow curves.*

The calculation of the effect of a number of aerials is complicated due to their mutual effect on each other. Assuming N aerials in a given area at A and that they produce at P an effect N times that of the single aerial, the expression becomes

$$E = K\sqrt{\left[1 - \frac{2AN}{\lambda Z_A}\sin\phi + \left(\frac{AN}{\lambda Z_A}\right)^2\right]}$$

It is now possible to work out a practical case of the variation of E with λ round about the resonant wavelength. The case taken will resemble as closely as possible the condition holding in the transmission from Teddington to Kew.

From an inspection made of the intervening district, and by studying a large-scale map, a rough estimate can be made, taking

$N = 500$; $h_A = 10$ m. ;
$d = 2$ km. ; $R = 50$ ohms ;
$x = 5$ km. ; $C = 200\ \mu\mu$F.

Assume that the aerials are tuned to 2LO ($\lambda = 360$ m.). The resultant curve of E with respect to λ is shown in Fig. 8, where the minimum value of the resultant field occurs at about 335 m..

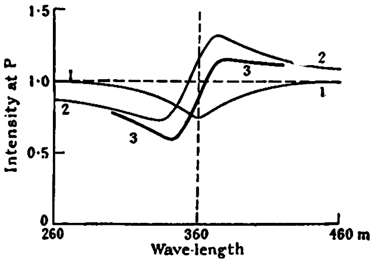


Fig. 9.—*Curve* 1 : *Energy absorption curve.*
Curve 2 : *Aerial shadow curve.*
Curve 3 : *Sum of curves* 1 *and* 2.

Combination of Absorption and Shadow Effect.— In practice these two effects will be combined, so that addition of a typical curve of each case should get somewhere near to the resultant effect. This superimposition is shown in Fig. 9, where the curve is clearly of the same nature as the experimental curve. In particular it has its minimum just below the resonant wavelength.

Conclusion.

The experimental results show that the attenuation over large towns is different from that over country. Over the town itself the attenuation is determined by the absorption of energy in the vertical metal conductors, pipes, steel frame works, etc., and possibly by dielectric losses in brickwork, etc. This attenuation increases rapidly with frequency. From theoretical reasoning, based on Sommerfeld's investigation, this appears to be consistent with the assumption that the losses occur in the vertical conductors. Tuned aerials in the dense part of the towns absorb little energy compared with that absorbed by other conductors, as such aerials are usually inefficient and heavily screened.

Over the suburbs this rapid attenuation disappears but tuned aerials play an important part. The experiments show that a comparatively small area of about 5 km.² may produce a selective decrease of signal strength to half normal value,

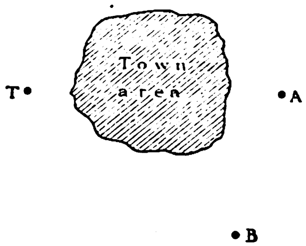


Fig. 10.

while the wavelength for lowest signal strength is slightly below that to which the aerials are tuned. The actual position of the minimum appears to vary with the number of aerials traversed

The results can be used to some extent to discuss the effect of towns in connection with proposed broadcasting schemes. If transmitter T (Fig. 10) works on 440 m. and 260 m., at receiver B the intensity on 440 m. is 6 mV./m. and on 260 m. (for the same power radiated) it will be about 2 mV./m. At A the experiments show that the strength on 440 m. will be about the same as at B, whereas on 260 m. it will drop to about 0.4 mV./m. In other words, it appears that at the upper limit of the broadcasting range towns have little effect, whereas on the lower range they cast a decided shadow.

APPENDIX.

Experimental Confirmation on Short Wavelengths.

The appendix describes check measurements carried out on an experimental scale to imitate the conditions. The wavelengths were less than 1/10th of those formerly employed as it was possible to produce the same shadow effect with a much smaller number of aerials. This is due to the fact that on short waves the radiation resistance of the aerial tends to predominate over the ohmic resistance. With the absorbing aerials under control the effects can be obtained by tuning these aerials, so that frequency characteristics of the transmitter and receiver are eliminated.

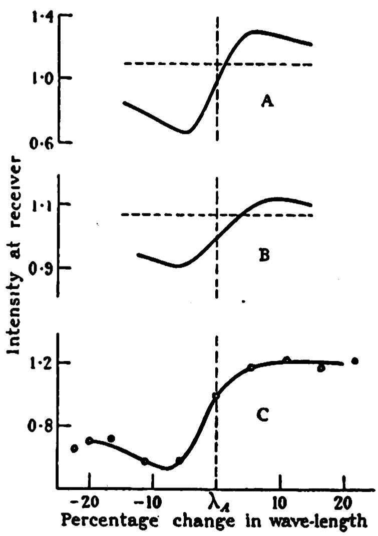


Fig. 15.—*Comparison of theoretical and experimental curves. Horizontal dotted lines show intensity, in the absence of the disturbing aerials.*

A low-power transmitter first sent on 24 m. to a single absorbing aerial 200 yards away while measurements were made at a receiver half-a-wavelength beyond it. The absorbing aerial was tuned down to 21 m. and up to 28 m.

Five aerials were then formed into the corners and centre of a square and the measuring apparatus moved to one wavelength from its centre. Transmissions on 20 m. and on 28 m. were also made.

The similarity between the results obtained with the experimental model and those for transmission over the suburbs of London is very striking. The comparison is given in Fig. 15, where B is for the experimental group, while A is the calculated and C the measured curve for London suburbs, redrawn from Fig. 9.

The work described in the paper is part of the programme of the Radio Research Board and is published by permission of the Department of Scientific and Industrial Research.

Discussion

The discussion which followed the reading of the paper was opened by Capt. R. P. Eckersley, who said that the paper was of particular interest to the B.C.C., and had an important influence on the general question of siting stations. Should the station be inside the town and work out, or outside the town and work in ? The paper was of help in considering this problem. Undoubtedly the effects described did exist. In surveying for the London Regional Station, they had made many measurements and found that the field-strength on the other side of London was about 0.6 of what it should have been. He would ask the authors, if the radiation did not obey Sommerfeld's law, could not another value of conductivity be given for various types of ground ? As regards the action of aerials, he had himself tried to calculate the effect in terms of the energy absorbed in each aerial, and had concluded that there were not enough aerials. He agreed that the effective height of 30 metres for the 2LO aerial might be subject to variation, and added that while the current in the aerial was about 9 amperes, that in the masts was considered to be more of the order of 2 amperes.

Mr. R. A. Wilmotte referred to the large quantity of original matter contained in the paper. With reference to the subject of dielectric losses, he had measured the dielectric losses in a powdered brick (results of which were exhibited in a slide). It was normally considered that dielectric loss varied but little with frequency. One possible source of error in measurement was the frequency characteristic of the transmitting antenna. The polar diagram might also have a frequency characteristic, *e.g.*, reducing the frequency might vary the polar curve. This would affect the values of Fig. 6. He also discussed the distortion of the field due to one aerial (as in the experimental model) and the effect of the masts in giving the polar diagram of 2LO, building up from consideration of the phase of the field due to the aerials and that due to the masts.

Mr. J. McPetrie also referred to the model experiment (of the Appendix) and to the distance at which the measurements had been made. At the distance quoted, the field was not completely a radiation field, and the necessary corrections, which he showed in a slide, moved the theoretical curve in the direction of closer agreement with the experimental.

Mr. E. B. Moullin thought that the effect of the building on which the transmitter stood could be estimated to get an idea of the effective height. Altering the earth-lead might have an effect on the polar diagram. As regards the authors' estimate of the effect of N aerials, he suggested that

the effect was comparable to theories of light due to Rayleigh, from which $\sqrt{N}$ might be a more likely value. This would alter Fig. 8 considerably.

MR. R. A. WATSON WATT suggested carrying out the investigation of the disturbing effect of receiving aerials over much greater distances, while MR. BAINBRIDGE-BELL asked if it would be possible to have all the aerials in a neighbourhood switched off simultaneously—say, by advice of the transmitting station—while a measurement was being made.

DR. R. L. SMITH ROSE amplified Mr. McPetrie's remarks on the calculation in the case of the model experiments. He offered the criticism that the work was all done outside ordinary broadcasting hours.

MAJOR BINYON also referred to this point, and asked if any observations had been made from say 3 p.m. to 9 p.m. continuously, and whether there was any trace of a maximum effect with aerials being brought into circuit.

MR. H. L. KIRKE said that in doing polar curves about London, they had found differences according to the amount of London embraced. It would be interesting to have, if possible, a value for effective conductivity for normal towns. The B.C.C. were doing work on the attenuation due to towns, and also on the effect of masts.

MR. R. H. BARFIELD briefly replied to several of the points raised. In reply to Capt. Eckersley, he said that the particular value of effective conductivity to fit Sommerfeld's theory would be different for each district of towns and for different wavelengths. In reply to Mr. Wilmotte he said that allowance had been made in the curves for the directional effect of the aerial. In reply to Major Binyon, he doubted whether it was a prevailing practice for listeners to earth aerials when not in use.

On the motion of the Chairman (Commander J. A. Slee, C.B.E.), the authors were cordially thanked for their paper.

The Chairman also announced that, at the next meeting, on January 2nd, a paper on "The Design of Aerials for Broadcast Transmitters" would be read by Capt. Eckersley, Mr. T. L. Eckersley, and Mr. Kirke.

Correspondence.

The Transmitting Station actually sends out Waves of one Definite Frequency, but of varying Amplitude.

To the Editor, E.W. & W.E.

SIR,—From Professor Howe's reply in your November issue, it is evident I did not make my point at all clearly in my letter. The real tilt was at the inconsistency of the treatment. Presumably the current in the receiving circuit can still be called a wave of one definite frequency varying in amplitude (provided the receiver is broad tuned enough), but it is found more convenient to treat the wave here as a spectrum of frequencies, so why not consider the current at the transmitter in the same light and get away from the single frequency idea; surely it is more heplful and just as accurate. For instance, will Professor Howe tell us how he can treat from the single frequency basis, "suppressed carrier" or "single side band working," *i.e.*, a modulated wave from which the carrier wave (or carrier and one side band) has been suppressed. Presumably since one has only one wave to deal with, we must suppress that portion of it which we consider as of constant amplitude and radiate that portion we consider as varying. Such a picture is reminiscent of the smile on the face of the Cheshire cat, where if it is remembered, the face disappears leaving the smile (I apologise for such a simile in a serious technical journal); but no doubt Professor Howe can give us something better and I should be very indebted to him if he can give an illuminating treatment of the suppressed carrier case from the single wave basis.

A minor tilt was whether it is not misleading to call any wave or group of waves which can be analysed into component harmonic waves, as consisting of one definite frequency. Should we not reserve such a term solely for a periodic sine wave? The qualification that there is an amplitude variation in a group does not clear matters, as it is insufficiently realised that an amplitude variation alters the whole complexion of things. This, of course, is really quibbling, but I suggest that it is our lack of concise terminology that is responsible for many of us having hazy ideas on wave formation.

I apologise for misquoting Professor Howe even though the portion misquoted is not in question.

A. W. LADNER.

Effect of Frequency on the Value of Resistances.

To the Editor E.W. & W.E.

SIR,—In the current issue of *E.W. & W.E.* I notice an article describing some tests carried out on grid leak resistances. As that article contains a somewhat misleading statement I will be obliged if you will permit the necessary correction to be published.

The author describes a grid leak resistance of the varnish impregnated strip type as "the usual type of Dubilier leak." Grid leaks of this type have been obsolete for some years and have not been manufactured or marketed by the Dubilier Condenser Company since 1925. It is also implied that another type of Dubilier grid leak consists of "the strip surrounded by a glass enclosure." I would like to point out that no resistances constructed in such a manner have been manufactured by the Dubilier Company. As the only type of grid leak resistance now manufactured by that Company and known as a "Dumetohm" resistance consists of a glass filament with a metallised coating which is sealed inside a glass tube, it would be interesting to know whether or not the resistance tested by Mr. Jackson was of this pattern in order that any possible misunderstanding may be removed.

PHILIP R. COURSEY, Chief Engineer,
Dubilier Condenser Co. (1925) Ltd.

Abstracts and References.

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PROPAGATION OF WAVES.

SHORT WAVE ECHOES AND THE AURORA BOREALIS. C. Störmer. (*Nature*, 3rd November, 1928, V. 122, p. 681.)

J. Hals of Oslo reported echo-signals from Eindhoven, arriving three seconds after the true signal. Störmer connects these with his theory (1904) on the Aurora Borealis, one feature of which was the idea that streams of electrons coming towards the earth are deviated by the earth's magnetic field in such a way that an immense space is formed free from electric particles, and having the shape of a torus described by the revolution of an oval tangent to the magnetic axis of the earth at the centre. Birkeland's results with cathode rays directed towards a magnetic sphere fit in with this theory. Now if wireless signals could penetrate the Heaviside layer they would pass into this empty space, and might be reflected by the walls of electrons forming its outer boundary. The long time interval between the signal and the echo agrees well with the immense dimensions of these toroidal spaces. Störmer and Hals have now confirmed these long-time echoes, obtaining during last October echoes from Eindhoven with intervals varying from three to fifteen seconds: sometimes two echoes were heard with an interval of about four seconds. Similar results (three—fifteen seconds) were noted by van der Pol at Eindhoven the next night: 50 per cent of the echoes were heard after eight seconds. The writer points out that the study of this new phenomenon may throw much light on the electric currents in space outside the earth and on their connection with the Aurora Borealis and magnetic storms.

In a similar paper to the French Academy (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 811–812) the writer suggests that the rays entering the space are reflected by currents or surfaces of corpuscles moving outside the space. The minimum distance from earth to the point of reflection, according to his theory, would be equal to $(\sqrt{2}-1)\sqrt{\frac{M}{H\rho}}$ cm., where M is the magnetic moment of the earth ($=8.4 \times 10^{25}$) and $H\rho$ a product characteristic of the corpuscles, equal to $\frac{m}{e} \cdot v$, where m is the mass, v the velocity, and e the charge in c.g.s. electromagnetic units. From this formula, the echo-interval comes out at 15 secs. if the reflection is from currents of cathode rays corresponding to $H\rho = 300$, and at 4 secs. if the currents are formed of radium β rays corresponding to $H\rho = 4{,}000$. These calculated values agree well with the observed times. The paper is followed by remarks by H. Deslandres, who quotes particulars of the sun's condition at the dates in question, which show that on the 11th October, when the first results (February) were confirmed, the condition was favourable to the strong emission of particles—and particles, moreover, from different points of the sun and possessing different velocities: which would explain the remarkable fact that successive echo-times were so different within the space of half an hour.

RADIO ECHOES AND MAGNETIC STORMS.—S. Chapman. (*Nature*, 17th November, 1928, V. 122, p. 768.)

Referring to Störmer's letter (see above) the writer remarks that the reflection of 31.4 m. waves back to earth from a great distance involves an electron density of the order of 10^5 to 10^6 per c.c.; that these electrons (at that distance from the earth) must be accompanied by an approximately equal number of positive ions; and that the density of the stream may thus be considered as similar to that of the solar chromosphere, or greater than this at emission. Also, that the presence of the positive ions will render the electron motions in the earth's field very different from those deduced by Störmer in his Aurora calculations.

RADIO ECHOES AND MAGNETIC STORMS: ATMOSPHERIC "WHISTLERS."—T. L. Eckersley (*Nature*, 17th November, 1928, V. 122, p. 768.)

The writer considers that the phenomena of "whistlers" (a class of atmospheric heard in telephones connected in series with a large aerial) fit in well with Störmer's explanation of the long-time echoes. Whistlers are definitely associated with magnetic storms, and on many occasions they occur in groups of echoes preceded by a violent click, the interval between the click and the first echo being approximately 3 secs., and between successive echoes about 3.8 secs. As many as 7 echoes have been heard: each successive echo is spread over a longer period than the last. The suggestion is that the original pulse spreads into the toroidal ring and circulates round it five or six times before its extinction.

A STUDY OF SHORT-TIME MULTIPLE SIGNALS.—J. B. Hoag and V. J. Andrew. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1368–1374.)

This paper deals with the intermediate type of multiple signals (arriving from 0.01 to 0.04 sec. after the direct signal, and therefore between the latter and the first "round-the-world" signal) discussed by Taylor and Young (these Abstracts, pp. 460–461, 1928). These particular signals were observed at Chicago, on 23–30 m. waves, whereas Taylor and Young were working with 15–21 m. Photographic (oscillograph) records are shown and from these the short-time echoes are divided into two classes: the "normal," in which the echo

signals are of the same form as the direct-signal, though of smaller amplitude—in the fraction of a second between the dots a considerable variation both in time and intensity occurs, indicating great instability in the paths followed : and the "wedge-shaped," in which either the signal dwindles down at the end or is extended by a dwindling "hang-over"—the evidence does not decide between these alternatives. The dwindling is not a case of rapid fading, since it has repeatedly appeared at times when fading was slight. If the wedge-end is not part of the signal but an extension, it may be due to a large number of multiple paths (corresponding to the case mentioned by Heising—*ibid*, January, 1928—of transmission of a short jab and reception of a longer diffuse signal). The writers suggest that certain of the short-time echoes fit in well with Taylor and Young's idea of reflection from regions of high electron concentration near the magnetic pole, and point out that other time intervals would conform with the picture of reflection by the Aurora Borealis (known to be most prominent above N. America in latitude 60°N. and in the N. Atlantic). They are particularly disposed to attribute the "wedge-type" signals to the Aurora. For the longest time-interval signals they suggest an inverted bowl-like "lifting" of the Heaviside layer above the geographic north polar regions due to their comparative darkness for many months of the year : the rays being reflected around the inner surface of the "bowl." They also mention the vertical component of the layer along the twilight zone, which would serve as a source of horizontal reflection or refraction for rays travelling at a certain elevation and impinging at a certain angle. The writers express the hope that additional information may be obtained, especially from stations farther North, and including directional and polarisation data.

Über die Wellenausbreitung in einem dispergierenden Medium (Wave propagation in a dispersive Medium).—K. Sreenivasan. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 121–124.)

Neglecting the effect of the earth's magnetic field and of the movement of the medium, the paper investigates mathematically the motion of an electron under the influence of an electromagnetic radiation field, in an atmosphere of free electrons whose energy loss by collision is negligible. The velocity of propagation suffers dispersion ; the group-frequency being smaller, the higher the frequency of the wave. At a certain critical frequency, depending on the electron-density, the group velocity becomes zero : the medium becomes opaque to the corresponding wave. The dispersion has the result, on the transmission of wireless signals, that the partial frequencies of a modulated wave arrive at different times, so that distortion of the modulation is caused. This effect decreases when shorter wavelengths are employed. The writer suggests that a test of great interest would be to transmit signals with a large number of harmonics (*e.g.*, squarely modulated waves) and to record the resultant signals by a Braun tube or similar device on a rapidly moving film : taking care that the amplifier used was distortionless.

Long Wave Radio Reception and Atmospheric Ozone.—G. M. B. Dobson. (*Nature*, 10th November, 1928, V. 122, pp. 725–726.)

The writer adds a note of warning to Sreenivasan's letter under the above title (Abstracts, December, 1928). He points out that the steady decrease in the ozone values during the period in question is due to the regular annual variation of ozone found in regions outside the tropics : and the danger of assuming a direct connection between two quantities where the variations of at least one of them are chiefly due to an annual periodicity, and particularly where the two values show only a steady increase or decrease during the period under review. There is no evidence of any world-wide variations of the amount of ozone : results at low latitudes (not India) indicate that the annual variation of ozone in these latitudes is very small.

Remarques sur la Diffusion de la Lumière et des Ondes Hertziennes par les Électrons Libres (Remarks on the Diffusion of Light and Hertzian Waves by Free Electrons.)—Ch. Fabry. (*Comptes Rendus*, 3rd November, 1928, V. 187, pp. 777–781.)

An electron in the path of a ray of electromagnetic radiation takes on a vibratory movement under the influence of the electric field, and radiates in its turn in all directions. Unlike molecular diffusion, this electronic diffusion is independent of the wavelength ; for example, one of the relations here obtained is that the free electron diffuses six times the energy which it intercepts, and this holds good whether the waves are light waves or those used in wireless. But in reality the waves encounter not one free electron but a great number, and as a result the independence of wavelength vanishes. For the short waves of light, there is no phase relation between the separate waves sent out by the electrons even in quite a small area ; it is only the intensities which add together. Thus with the degree of ionisation occurring in nature, diffusion of light rays by electrons is always very slight, and plays no appreciable part in the production of the light of the sky ; though it may—as Dufay suggests—in certain astrophysical phenomena. But with the waves used in wireless, the case is very different ; all the electrons contained in a large volume take up corresponding movements and send out into space waves whose amplitudes add together, giving an intensity enormously greater than the sum of the intensities which would be produced by the individual charges. Thus an intense wave can be produced by a relatively small number of electrons, and one can have—according to the shape and size of the areas holding the electrons—either a regular true reflection or a complete diffusion in all directions. Between these two extremes, many intermediate results are possible ; for example, a layer of little thickness and of horizontal dimensions which are not very large compared with the wavelength would give a mixture of reflection and diffusion. Finally, if the layer is thick in comparison with the wavelength, the optical "thin film" effect may be realised, and if the ray is not strictly "mono-

chromatic" there may result unequal reflection of the various frequencies and an apparent change of wavelength on reflection. This paper is the result of thinking over Jouaust's article (Abstracts, 1928, p. 578).

THE INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON ELECTRIC TRANSMISSION IN THE UPPER ATMOSPHERE.—S. Goldstein. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121, A., pp. 260–285.)

The writer develops a formula for the general problem (when the magnetic field is oblique to the direction of propagation) which appears to correspond with that given by Appleton to the U.R.S.I. in 1927 (Abstracts, December, 1928). After applying the formula to the special cases (field perpendicular to or along the direction) and deducing the resulting states of polarisation, the writer considers the "forbidden" wavelengths for various values of N (effective ions per unit volume), and the variation of the refractive index with N for a given wavelength.

In the light of his deductions he then considers the polarisation measurements of Appleton and Ratcliffe (Abstracts, p. 221, 1928) on approximately 400 m., where those workers ascribe the observed absence of the right-handed polarised wave to increased dissipation of energy by collisional friction. This explanation he finds at first unsatisfactory, asking for too much damping in such a short path; but after considering alternatives he agrees that the fact must be that the bottom of the ionised layer is much lower than 100 km., and that the density of ions up to about 100 km. is sufficient to cause considerable damping, though not considerable bending, in a 400 m. wave. A further deduction is that the right-handed component should be in greater strength in the middle of a winter night than just after sunset or before sunrise; also, that multiply reflected rays should be more in evidence in the middle of the night than at other times. With regard to the energy in the downcoming wave, he works out the ratio downcoming wave/incident wave as approximately 0.29 for W to E transmission and 0.47 for S to N; these values being upper limits and on the large side. (*Cf.* the old tradition among Wireless engineers that E and W communication was always more difficult than N and S: this was provisionally attributed to sunlight effects.—*Abstr.*). Summarising the results of the various workers, he agrees with Appleton (*Nature*, 1927, V. 100, p. 330) in picturing a three-fold layer: 40–70 km. effective height for long waves; 90–110 for waves in the Broadcasting band; and 200–250 for short waves. He considers the distribution of ionisation: the bottom layer is connected with the ozone layer and is also, roughly, that in which occurs the Lindemann-Dobson temperature inversion: the height of the middle layer coincides roughly with the auroral height; the upper layer must (if Chapman and Milne are right) be predominantly helium, but there is some difficulty in accounting for the large ionisation required in the short distance transmission of short waves. The paper concludes by considering the polarisation of very short and very long waves.

DER EINFLUSS DER ERDATMOSPHÄRE AUF DIE AUSBREITUNG KURZER WELLEN (The Influence of the Earth's Atmosphere on the Propagation of Short Waves).—J. Fuchs. (*Zeitschr f. Hochf. Tech.*, October, 1928, V. 32, pp. 125–129.)

An investigation with the object of establishing a definite relation between meteorological changes and the propagation of wireless waves. For this purpose the writer considers short waves (under 100 m.) to be more useful than long waves, as they avoid more than the latter the local and inconsistent variations of the troposphere and of earth conductivity, and are chiefly affected by the more consistent changes in the stratosphere. He uses, therefore, the Time-signals from Washington on approx. 75 m. and 37.4 m. received in Vienna: over about 2,000 km. of land, 3,000 km. of sea, and another 2,000 km. of land; the period being 29th December, 1927, to 29th February, 1928, when the sun was still well below the horizon at Vienna at the time of the programmes. The first figure shows the curves of audibility of the two sets of signals, compared with curves showing the temperatures at Washington, Belle Isle, Ireland and Vienna, and the atmospheric pressures over America and Europe. In spite of a certain apparent agreement between signal audibility and the Washington temperature curve, the writer concludes that there is no definite relation between the signal strength and the American or European temperature curves. Nor can any satisfactory correlation be noticed between signals and the individual atmospheric pressure records on the diagram. At this point, however, the writer introduces records, from the German Marine Observatories, of the atmospheric conditions over the whole 7,000 km. By classifying this material into "high, medium or low" pressures over "America, the Atlantic and Europe," he obtains a table from which he deduces the following conclusions:—(1) 75 m. wave. Fall of pressure results in increase of signals. (2) 37.4 m. wave. A rising gradient from Washington to Vienna gives strongest signals: a falling gradient gives weaker signals. Some readers would perhaps interpret the table rather differently, particularly as the weakest signal strength corresponds with conditions "low, low, low" over the whole distance; and at least one of the strongest signals corresponds with "high" over America, "low" over the Atlantic and "high" over Europe, so that the important gradient would here seem to be Atlantic-Vienna rather than Washington-Vienna. (3) The 75 m. wave is as strong as or stronger than the 37.4 m. wave, when a depression is over the Atlantic and either a depression or a medium pressure is over Europe; but in the latter case the writer postulates the absence of high pressure over America.

On these and other data the writer explains the relative behaviours of the two waves as a result of alteration of skip-distance due to a dispersion (resembling a diffuse reflection) whose magnitude depends either directly or indirectly on pressure changes. It is right to mention that aural methods were only used after they had been proved so reliable that there was no need to take field-strength measurements.

ELIMINATION OF FADING.—(U.S.A. Patents Nos. 1,669,218 and 9, Taylor, 8th May, 1928.)

In the second patent, two separate aerials each have a separate receiver with its own local oscillator; the outputs of the two receivers are combined in a common telephone. The two local oscillators generate heterodyning waves of different frequencies, so that the heterodyne notes themselves are of different pitch and cannot interfere with each other when combined in the telephones, as they would do if their pitches were equal. In the first patent, the arrangement differs in that the two receivers are provided with reaction so as to dispense with local oscillators; the autodyne notes are arranged so as to be different, and each is received in one ear-piece of a binaural telephone headgear. *Cf.* Abstracts, 1928, p. 684.

THE VARIATION OF DIELECTRIC CONSTANTS OF AIR AND CARBON DIOXIDE WITH WAVE-LENGTH (600–60 m.).—M. Forró. (*Zeitschr. f. Phys.*, 18th October, 1928, V. 51, pp. 374–377.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

L'ÉTÉ 1928 ET LES VARIATIONS SOLAIRES (The Summer of 1928 and Solar Variations).—H. Mémery. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 831–833.)

The writer considers that with very few exceptions, the cause of all abnormal variations in temperature in our regions can be found in the variations of sun-spot phenomena. He quotes the very different sun-spot records of the summers of 1927 and 1928 as an example of bad and good summers, and mentions a number of other summers since 1827 which show a similar correlation.

SUN-SPOTS IN WEATHER PREDICTION.—H. N. Russell. (*Scient. American*, June, 1928, pp. 512–513.)

"It is now impossible to predict the weather from sun-spots, and such predictions need not be taken seriously."

ACTIVITÉ SOLAIRE ET MAGNÉTISME TERRESTRE (Solar Activity and Terrestrial Magnetism).—Ch. Maurain. (*L'Onde Élec.*, October, 1928, pp. 413–427.)

The writer mentions that it happens fairly often that no spot is visible on the sun during a day of magnetic disturbance: further, that no spot may appear several days before or after. But results averaged over 40 years show that there is a very definite correlation between magnetic disturbance and solar activity, the former coming on an average 2½ days after the latter. He points out that the spots themselves are merely a particular symptom of abnormal solar activity, which need not always be accompanied by them; also, that there is good reason to believe that certain magnetic disturbances have their origin in the earth's atmosphere and are independent of solar activity. The paper concludes with a consideration of the periodic variation, yearly and daily, of magnetic agitation; the former is apparently indirectly influenced by solar activity, the latter is apparently quite independent of it.

SUR UN ORAGE OBSERVÉ AU PIC DU MIDI, ET SUR LA FORMATION DE LA GRÊLE (A Storm on the Pic du Midi, and the Formation of Hail).—C. Dauzère. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 835–837.)

From his observations the writer concludes that atmospheric electricity plays an important part in the formation of hail. The droplets in the cumulo-nimbus, for the most part negatively charged, are attracted by the little crystals of ice in the cirrus into which the cumulo-nimbus rises; these crystals having attained a positive charge by ultra-violet light. The droplets congeal round each crystal, and form a hail-stone out of each. The hail-storm ceases when the supply of crystals is exhausted; the hail-stones must be either positive or neutral, which is confirmed by the observations of MacClelland and Nolan.

PROPERTIES OF CIRCUITS.

SOME PRINCIPLES OF GRID-LEAK GRID-CONDENSER DETECTION.—F. E. Terman. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1384–1397.)

Author's summary: The action taking place in this method of detection is reduced to an equivalent circuit consisting of the grid-leak condenser impedance in series with the dynamic grid resistance. The effect of applying a signal voltage to the detector, as far as the rectified grid current is concerned, can be represented by the introduction, in the equivalent circuit, of a fictitious voltage that is determined by the signal, and by a single valve constant called the "voltage constant" $\left(2R_g \Big/ \frac{dR_g}{dE_g}\right)$ as used by Carson (*ibid.*, June, 1921). The voltage drop produced by this fictitious voltage across the grid-leak condenser impedance is the change of grid potential resulting from the detector action. A bridge method of measuring all detector constants is described. The effects of grid leak and condenser sizes are discussed, and the factors involved in the selection of conditions for best detection with telephone and telegraph signals are considered.

LES TRANSFORMATEURS INTERMÉDIAIRES EN BASSE FRÉQUENCE (Inter-valve L.F. Transformers). R. Jouaust. (*L'Onde Élec.*, October, 1928, pp. 437–445.)

Miller has shown that owing to the internal capacities of the valve there is always, in the grid-filament circuit, a degradation of energy corresponding to a fictitious resistance depending on the anode charging circuit; being different according as this circuit possesses resistance only or resistance plus inductance or capacity. One important consequence is that an inter-valve transformer can only be studied properly under conditions corresponding as nearly as possible with working conditions. The writer begins with a mathematical treatment of L.F. transformers, describes a bridge scheme for quantitative investigation, and finishes

by considering the effects of leakage and the virtual grid filament resistance discussed by Miller.

RADIO VALVE ANODE CAPACITIVE RESISTANCE. (*Elec. Review*, 10th August, 1928, and following numbers.)

An argument by various writers, started by an article by E. W. Braendle.

COMPENSATION FOR INNER VALVE CAPACITIES. (German Patent 464,096, Koomans, published 10th August, 1928.)

With multi-grid valves the undesired internal capacities can be compensated for by the natural capacities between the grids. Two simple circuits are illustrated in which this effect is produced by suitable adjustment of a tapping along a coil in the circuit inside-grid-anode. If the capacity between control-grid and anode equals that between the two grids, the tapping-point is at the mid-point of the coil.

THE HEARTBEAT CONSIDERED AS A RELAXATION OSCILLATION, AND AN ELECTRICAL MODEL OF THE HEART.—B. van der Pol and J. van der Mark. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 763–775.)

An English version of the paper referred to in Abstracts for December, 1928. A remarkable list of phenomena forming instances of these oscillations is given, including an æolian harp, the scratching noise of a knife on a plate, the humming noise sometimes made by a water-tap, the Abraham-Bloch multivibrator, the Wehnelt break, the periodic sparks from a Wimshurst machine, the sleeping of flowers, and the periodic density of an even number of species of animal living together, and one species serving as food for the other.

AMPLIFICATION OF LONG WAVES. (German Patent 464,227, Lorenz, published 14th August, 1928.)

This patent was applied for on 4th February, 1921. It deals with the heterodyning, in one or more steps, of long waves to produce a suitable frequency increase.

TRANSMISSION.

HIGH FREQUENCY A.C. GENERATION.—E. D. McArthur. (*Elec. Review*, 24th August, 1928, V. 103, pp. 303–306.)

Description of an American transmitting valve (G.E.C.) with a water-cooled anode whose diameter is about three times that which is usual. Not only does this enable 20 kW. to be dissipated by a flow of water of 3 gallons per minute, but the decreased inter-electrode capacity allows very short waves to be produced. Experiments are described with 5.6 m. waves, dramatic effects such as the cooking of food by a neighbouring receiving aerial being quoted. Physiological effects (headache, etc.) are mentioned. (A. M. Codd, however—*ibid.*, 7th September—explains these as the normal results of excessive diathermy, which can be produced by quite small apparatus.) The grid and filament are of conventional design and size, but the anode is 9in. long and 3⅛in. in diameter. Details of workings are as follows:

Plate Voltage.	Plate Current.	Power Output.	Megacycles Frequency.
12,000 V.	1.9 A.	15.0 kW.	49.2
10,000	1.4	5.0	60
8,000	0.7	0.8	69.8

ZUR FRAGE DER ERZEUGUNG KURZER ELEKTROMAGNETISCHEN WELLEN (The Production of Short E.M. Waves).—M. Grechowa. (*Physik. Zeitschr.*, 15th October, 1928, pp. 726–729.)

An investigation of the Barkhausen oscillations by the use of specially designed valves in which the various constants can be readily calculated. The conclusion is that every valve possesses a series of internal oscillating circuits, each of which can be excited by a suitable adjustment of working conditions. The observed oscillations agree very well with the values thus calculated, though not all the calculated overtones could be detected in practice.

IMPROVEMENTS IN VALVE OSCILLATOR CIRCUITS. (German Patent 462,980, Trautwein, published 21st July, 1928.)

A "linking resistance" is connected in the part of the circuit common to anode and grid—*i.e.*, close to the filament connection—and is so proportioned that at the setting-in of oscillation the anode current is cut down to exactly, or nearly, the same value as it had before. If a condenser is connected in parallel with this resistance, under suitable conditions a self-modulation is set up. If the oscillator is tuned to the frequency of incoming waves, these can be made evident by the alteration of the modulating frequency.

DER WEHNELT-UNTERBRECHER ALS GENERATOR ELEKTROMAGNETISCHER SCHWINGUNGEN (The Wehnelt Break as an Oscillation Generator). —W. M. Schulgin. (*Physik. Zeitschr.*, 15th October, 1928, pp. 724–726.)

By connecting in the manner opposite to the usual, so that the platinum electrode goes to the negative pole, the writer uses the Wehnelt break as the "simplest and cheapest oscillation generator."

ON THE PRODUCTION OF INTENSE UNDAMPED ELECTRIC WAVES OF EXTRA SHORT WAVELENGTHS.—K. Okabe. (*Tech. Rep. Tôhuku Imp. Univ.*, No. 4, 1928, V. 7, pp. 1–28 and 2 plates.)

A paper by the same author on his split-anode magnetron work was briefly abstracted on p. 399, 1928. The present report is in English, and is on the same lines. The split-anode design allows the use of a resonant circuit, which does not give good results with the ordinary anode. The shortest fundamental wave now reached is 12cm., the shortest harmonic, 8cm. The most intense oscillation obtained was at 42cm. Various methods for

the projection and reception of the waves are described and illustrated by photographs of the valves, reflectors, etc. The "wave directors" of Yagi and Uda were employed for reception (Abstracts, p. 519, 1928), while a lattice-type aerial was used for transmitting. Numerous curves, tables, etc., showing laboratory results and the result of field tests are given.

ÜBER EINEN RÖHRENSENDER FÜR KURZE UNGEDÄMPFTE WELLEN (A Valve Transmitter for Short Undamped Waves).—L. Bergmann. (*Ann. d. Physik*, 2nd May, 1928, V. 85, No. 7, pp. 961–966.)

A circuit is described, using an ordinary commercial type of valve, which by suitable adjustment gives (with regularity) wavelengths from a few metres to about 82cm. Anode voltage 600, average anode current 40 milliamperes.

INCREASING THE EFFICIENCY OF A SHORT-WAVE TRANSMITTER. (German Patent 461,526, Telefunken, published 23rd June, 1928.)

Short-wave transmitters are often separately controlled by a crystal-driven circuit stepping up by a series of valve circuits, the last of which is coupled to the aerial circuit. According to the invention, a self-excited transmitter circuit is also coupled to the aerial circuit and has its grid circuit coupled sufficiently closely to the crystal-controlled circuits for it to be drawn into synchronism.

RECEPTION.

ON THE DISTORTIONLESS RECEPTION OF A MODULATED WAVE AND ITS RELATION TO SELECTIVITY. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, p. 1422.)

Further discussion of Vreeland's paper (these Abstracts, 1928, V. 5, p. 286). Raven-Hart points out that Vreeland does not appear to have taken into consideration the "demodulating" effect of a stronger on a weaker signal (Beatty, *E.W. & W.E.*, June, 1928, V. 5), which should increase the effect of selectivity.

RADIO RECEIVER VOLUME CONTROL.—N. W. McLachlan. (*Elec. Review*, 9th November, 1928, V. 103, pp. 825–826.)

Referring to Whittaker's article (see Abstracts, December, 1928), the writer mentions that the control should precede the detector, and describes the method he himself uses in the "Megavox" receiver.

PERMISSIBLE GRID SWING WITH A PENTODE: HOW THE VALVE AND THE LOUD SPEAKER MAY CAUSE RECTIFICATION.—N. W. McLachlan. (*Wireless World*, 31st October, 1928, V. 23, pp. 584–586.)

THE EUROPA III: A POST-EXHIBITION RECEIVER. —F. H. Haynes. (*Wireless World*, 21st November, 1928, V. 23, pp. 694–697.)

First part of a paper giving constructional details of a new receiver based on the experience of the recent exhibitions.

MARCONIPHONE SHORT-WAVE SET: A SENSITIVE SHORT-WAVE RECEIVER ADAPTABLE FOR LONG WAVES. (*Wireless World*, 31st October, 1928, V. 23, pp. 593–595.)

SALON DE T.S.F.: THE RADIO SITUATION IN FRANCE TO-DAY. (*Wireless World*, 7th November, 1928, V. 23, pp. 643–647.)

A review of the recent Paris Show, larger than the Olympia Radio Exhibition.

WAVEBAND SWITCHING—FROM SHORT TO LONG WAVES WITHOUT CHANGING COILS.—H. F. Smith. (*Wireless World*, 7th November, V. 23, pp. 625–629.)

SETS OF THE SEASON: A COMPARATIVE ANALYSIS OF THIS YEAR'S DESIGNS. (*Wireless World*, 14th November, 1928, V. 23, pp. 654–658.)

BUYERS' GUIDE, 1928–29.—The *Wireless World* Reference List of Receiving Sets. (*Wireless World*, 14th November, 1928, V. 23, pp. 663–672.)

AERIALS AND AERIAL SYSTEMS.

MULTIPLE ANTENNA SYSTEMS. (Austrian Patent 109,586, Surjaninoff, published 10th May, 1928.)

In the usual systems, in which separate aerials are fed by currents of adjusted phase differences, the aerials are so widely spaced that there is no magnetic field containing them all. According to the invention, more aerials are used, arranged as near together as the voltage allows. The phase differences between the individual feeding currents are so arranged that the total does not exceed 180 deg.: thus a magnetic field is produced containing all the aerials.

DIRECTIONAL PROPERTIES OF WIRELESS RECEIVING AERIALS.—D. Burnett. (*Proc. Camb. Phil. Soc.*, October, 1928, V. 24, pp. 521–530.)

Colebrooke's extension of Moullin's equations has shown that the intensity of the received signal is independent of the orientation of the receiver (antenna partly vertical and partly horizontal) if the wave is plane polarised with its electric vector vertical. The present paper investigates the effect of orientation of such a bent antenna, and also of the Beverage Aerial, in the reception of a wave such as is received in practice—namely with an incident wave front *not* vertical but tilted by an amount depending on the wavelength and the resistance of the earth.

VALVES AND THERMIONICS.

GAS-FILLED THERMIONIC TUBES.—A. W. Hull. (*Journ. Am.I.E.E.*, November, 1928, V. 47, pp. 798–803.)

In gas-filled tubes the electrons freely emerge from cavities ⅛ to ¼ inch wide and 4 inches deep. This makes it possible to use internally coated cathodes (heated indirectly), which are heat-insulated on the outside, so that the only appreciable loss of heat is that from the open end through

which the electrons emerge. Radial vanes, coated on both sides, increase the electron-emitting area many times. The combined result is that the tube can be operated at 1,000 deg. K., which would give only 24 mA. per heating watt for a filament, but 600 mA. per watt for the "shielded cathode." Since ions produce no disintegration when their kinetic energy is less than a critical value, the life of such a cathode should be more than seven years. The paper describes forms of Thyratron based on the use of such cathodes: the grids are large, and emit no electrons: they shield the whole cathode from the anode.

NOTE ON THE EFFECT OF TEMPERATURE ON THE AUTO-ELECTRONIC DISCHARGE.—N. A. de Bruyne. (*Proc. Camb. Phil. Soc.*, October 1928, V. 24, pp. 518–520.)

Leading from the work of the author and Pforte (Abstracts, 1928, pp. 582 and 642) and of Schottky, the author has separated the auto-emission from the thermionic and finds that the auto-emission is independent of the temperature up to 1,944 deg., the highest temperature investigated. He deduces that the statement of Millikan, Eyring, and Lauritsen (that above 1,000 deg. it is affected by temperature) is a wrong conclusion from results due to the beginning of thermionic emission above that point. He gives the equations for the total current, agreeing with the picture of the auto-electric discharge put forward by Fowler and Nordheim (Abstracts, 1928, p. 400). The auto-electrons come from the lower energy levels and are practically unaffected by the temperature of the cathode or the height of the potential-jump at the metal surface. The thermions come from high energy levels and are controlled almost entirely by these two factors.

EINFLUSS POSITIVER IONEN AUF DIE ELEKTRONEN-RAUMLADUNG INNERHALB EINES ZWEI-PLATTEN SYSTEMS (Influence of Positive Ions on the Electron Space-Charge in a Two-plate System).—H. Cohn. (*Ann. d. Physik*, 12th October, 1928, V. 87, No. 4, pp. 543–569.)

The type of valve dealt with was first used by de Forest and further applied by Wien: it has two equal parallel plates symmetrically on either side of the cathode.

ZUR THEORIE DER RAUMLADEGITTERRÖHREN (The Theory of the Space-Charge-Grid Valve).—F. Below. (*Zeitschr. f. Fernmeldtech.*, 29th August and 29th September, 1928, pp. 113–118 and 136–143.)

The space-charge-grid does not give the ideal rectangular characteristic hoped for by Langmuir and Schottky. The present paper investigates the reasons for its imperfect action, with a view to improving the design of the valve. The thorough theoretical and experimental work leads to the following practical conclusions: The space-charge-grid should be as fine-meshed as possible, to make the angle of deflection low; its radius as small as possible, so that the space-charge voltage may be kept small: the distance of the control-grid from the space-charge-grid should not be greater than 1.6 times the space-charge-grid radius, so that the secondary space-charge may be harmless: indirectly-heated equipotential cathodes must be used; the directions of the openings of the two grids should cross at right angles, the space-charge-grid being advantageously a spiral, the control grid a straight rod one. The space-charge voltage should be so high that when control voltage is zero, the saturation current flows to the space-charge-grid. Increase of voltage decreases the steepness. The steepness increases in proportion with the saturation current. At low temperatures the lower bend is very sharp.

SYSTEMATIC VARIATIONS OF THE CONSTANT A IN THERMIONIC EMISSION.—L. A. Du Bridge. (*Proc. Nat. Acad. Sci.*, October, 1928, V. 14, pp. 788–793.)

Richardson in 1915 discovered an empirical relation (for tungsten and platinum) which may be stated as follows: In the Richardson-Dushman equation $I = AT^2e^{-b/T}$ whenever the work function, b, of a given surface is changed by any method (heating, outgassing, coating, etc.) the constant A also changes in such a way that log A is a linear function of b. This relation seems to have been completely neglected by subsequent workers, who have regarded any found variations of A as due to surface contamination. The present writer's results with thoroughly cleaned platinum have shown that A may have values 200 times or more greater than Dushman's value of 60; Goertz has obtained similar results with nickel. The present paper collates the various published results and deduces, in agreement with Bridgman, an expression for A which is A_0e^{α}, alpha being interpreted as the negative temperature derivative of the (photo-electric) work function: it can be obtained from measurements on the shift of the photoelectric threshold with temperature. For tungsten it is zero, so that $A = A_0$; whereas for platinum a shift occurs which may give 4.5 for alpha—of the right sign and order of magnitude to fit in with the writer's results on platinum.

THE INCREASE OF THERMIONIC CURRENTS FROM TUNGSTEN IN STRONG ELECTRIC FIELDS.—R. S. Bartlett. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121, A., pp. 456–464.)

Author's summary: Experimental results for the increase of thermionic currents with applied electric field at constant temperature show general agreement with theory, but the departures from a predicted straight line are greater than can be accounted for by experimental deficiencies. In the dependence of this rate of increase upon temperature, the failure of experiment to agree with the theory is still more marked, even after due allowance is made for certain experimental difficulties. It is suggested that Schottky's equation should be modified to take account of the influence of neighbouring electrons close to the surface—electrons that emerge from the surface, but do not completely escape. Attention is drawn to the marked effect of surface impurities in the cathode upon the experimental results.

FIELD CURRENTS FROM POINTS.—C. F. Eyring, S. S. Mackeown, and R. A. Millikan. (*Phys. Review*, May, 1928, V. 31, pp. 900–909.)

The laws previously obtained by experiments with crossed wires, then with fine wire cathodes discharging to cylindrical planes, have now been found to hold for field currents between points and planes. The smallest current found possible to measure accurately required a field of 2,000 kV/cm for a platinum, and less than half that value for a tungsten point: the metal in each case forming the cathode. When the metal was the anode, 100,000 V (corresponding to 35,000 kV/cm) produced no detectable current.

THE EFFECT OF ELECTRIC FIELDS ON THE EMISSION OF ELECTRONS FROM CONDUCTORS.—A. T. Waterman. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121 A., pp. 28–40.)

The writer points out that Houston's recent explanation is a treatment of the Schottky effect, for very intense fields: that if the Sommerfeld electron theory is accepted, the expression for the Schottky effect should be modified, and that this modification becomes significant at high fields. The object of the present paper is to derive an expression, on the Sommerfeld theory, for the thermionic current in the presence of an electric field, and to point out the difficulties in the way of accepting the Schottky effect as the correct explanation of the "field currents." The writer concludes that the process involves some factor not yet considered, and that possibly it is only to be explained in some entirely different manner, such as the treatment recently presented by O. W. Richardson.

MESSUNG DER WÄRMEENTWICKLUNG BEI DER KONDENSATION VON ELEKTRONEN IN METALLEN (Measurement of the Heat developed by the Condensation of Electrons in Metals).—R. Viohl. (*Ann. d. Physik*, 5th October, 1928, V. 87, No. 2, pp. 176–196.)

Allowing for the effect of contact potential (which has vitiated the results of other experimenters) the value for nickel comes out at (97,800 ± 9,800) cal. per Mol.

ÜBER DIE AUSLÖSUNG VON SEKUNDÄRELEKTRONEN DURCH ELEKTRONEN VON 1–30 KILOVOLT.—E. Buchmann. (*Ann. d. Physik*, 12th October, 1928, V. 87, No. 4, pp. 509–535.)

DIRECTIONAL WIRELESS.

WIRELESS AS AN AID TO NAVIGATION.—Chetwode Crawley. (*Discovery*, November, 1928, V. 9, pp. 351–354.)

The short wave (about 6 m.) rotating beacons in the Firth of Forth and S. Foreland: the Orfordness rotating loop beacon: the fixed double loop, rotating double and single loops for ship-board: and the all-round beacons now being erected at various points on the coast, are briefly outlined.

ERROR-CORRECTION IN DIRECTION FINDERS.—(French Patent 635,849, S.F.R., published 26th March, 1928.)

To correct for errors due to masses of metal, steel masts, etc., the receiving loops are encircled by a guard loop provided with adjustable resistance and inductance.

ACOUSTICS AND AUDIO-FREQUENCIES.

ÜBER NEUERE AKUSTISCHE . . . (New Work on Acoustics and in particular Electro-acoustics). —F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, October, 1928. V. 32, pp. 131–135.)

Third part of the long survey dealt with in October and December Abstracts, 1928. The present instalment deals with sound-transmitters which have to reproduce as uniformly as possible a wide range of frequencies—*i.e.*, loud speakers and telephones for Broadcast reception. The principles and frequency-range curves of various types of loud speaker are given: including Riegger's copper band and multi-field design, the Rice-Kellogg, and Gerlach's "folded" design (including the four-leafed clover "Protos" type). Grützmacher and Meyer's curves for head-telephones, both electromagnetic and static, are given, the great superiority of the latter type being very evident. The instalment deals finally with the question of non-linearity of reproduction and its resultant introduction of partial frequencies which should not be present at all. Here the electrodynamic system comes to the fore, especially when great volume is required: the copper-band membrane, for example, can oscillate with a very large amplitude without the conductor leaving the field. Tables showing the non-linear distortion (measured by the ratio of the effective pressure-amplitude of overtones to that of the fundamental) for various types of loud speaker are given.

NUMERICAL VALUES CONCERNED IN TELEPHONY.—T. J. Monaghan. (*Electrician*, 16th November, 1928, V. 101, p. 550.)

Part of an address on "Communication Efficiency." The frequencies used in speech are about 80–5,000 p.s., and the average energy of an ordinary speaking voice is of the order of 10 μW, the power peaks in the vowel sounds rising to about 200 μW. Although the low frequencies are the ones of high energy content (more than 80 per cent. of the whole energy of speech being contained in the frequencies up to 1,000), yet these low frequencies can be cut off to quite a large extent before the speech begins to lose its intelligibility. The voice frequency A.C. input at the sending end of a telephone circuit is about a microwatt or two at half a volt. It is estimated that the minimum current to energise a good telephone receiver so as to give a signal audible to an attentive ear is of the order of 10^{-8} A, the amplitude of the diaphragm movement then being of the order of 10^{-9} cm.—less than the mean molecular diameter of the diaphragm material. In an ordinary telephone receiver one microwatt* gives a very loud signal, 0.25 a loud sound, and

* In a similar article in the *Electrical Review*, the writer gives these three values as milliwatts.

say 0.02 a good audible signal. At resonance of the diaphragm, the efficiency of a receiver is of the order of 1 per cent., and off resonance it falls very much below this. This indicates how sensitive the ear itself is: pressure variations of the order of a thousandth of a dyne will produce an audible signal (*i.e.*, 2×10^{-10} μW).

ENERGIES IN BROADCASTING.—(*E.T.Z.*, 25th October, 1928, p. 1580.)

In an article describing an Austrian Technical Exhibition, some interesting energy measurements are given: a normal speaking person delivers one-millionth of a watt: a microphone delivers about one-hundredth of this to the input amplifier. The whole amplifier gives, to a 15 kW. transmitter, about 10 W.: the transmitter (at rest) radiates 15 kW., a receiver takes up at most one 15-millionth part of this and delivers back one-millionth of a watt from the head-telephones.

A TESTING METHOD FOR MICROPHONES.—K. Kobayashi. (*Journ. Jap. I.E.E.*, September, 1928, pp. 960–974.)

A direct and absolute method of measuring the electro-acoustic pressure ratio. The sound-pressure is measured by a vibrometer provided with a special diaphragm, the E.M.F. produced is measured by a thermionic voltmeter.

EIN NEUER EINROHR-ZWISCHENVERSTÄRKER (A New One-valve Intermediate Repeater).—L. Müller. (*E.N.T.*, October, 1928, V. 5, pp. 403–411.)

Advantages are: cheapness compared with the usual two-valve repeaters, and insensitiveness to lack of symmetry in the associated lines.

UTILISATION DES LAMPES DE T.S.F. POUR LA PRODUCTION DE MUSIQUE ÉLECTRIQUE (The Use of Valves for the Production of Electrical Music).—E. Aisberg. (*L'Onde Élec.*, October, 1928, pp. 455–458.)

The "Dynaphone" of Bertrand, the instruments of Théremin and of Martenot are briefly dealt with.

ÜBER EINE EINFACHE METHODE DER AUTOMATISCHEN KLANGANALYSE UND DER MESSUNG DER NICHTLINEARITÄT VON KOHLEMIKROPHONEN (A Simple Method of Automatic Sound Analysis, and the Measurement of the Non-linearity of Carbon Microphones).—E. Meyer. (*E.N.T.*, October, 1928, V. 5, pp. 398–403.)

A method is described, accurate enough for most purposes, and dispensing with complicated amplifiers, resonance circuits, filter chains, etc.

It consists in the use of a circuit resembling a bridge circuit, supplied from a hummer with an A.C. of variable (pure) note frequency. In the diagonal of the bridge is an instrument which registers the magnitude of the difference-tone formed from the hummer frequency and that produced by the effect on the microphone of the partial tone in the sound under analysis. The measuring instrument is of too long a period to respond to the summation tone, and interference by the hummer frequency is obviated by the bridge circuit. The deflection is recorded photographically; the registering drum is mechanically linked to the rotating condenser of the hummer, so that the process goes on automatically.

PHOTOTELEGRAPHY AND TELEVISION.

DER BILDFUNK NACH DEM SYSTEM LORENZ-KORN (The L-K Picture Telegraph System).—W. Scheppmann and A. Eulenhöfer. (*E.N.T.*, October, 1928, V. 5, pp. 373–381.)

Description, illustrated by diagrams, photographs of apparatus, and specimen results, of the methods and apparatus used in the May, 1928, Berlin-Breslau trials (300 km., 600 W., 1,050 m.). Black-and-white and also half-tone pictures were used. Further developments, including a new synchronising method, are dealt with.

DERNIERS PROGRÈS DE LA TRANSMISSION BELINOGRAPHIQUE EN FRANCE (Latest Progress in Belinograph Transmission in France).—G. Ogloblinski. (*L'Onde Élec.*, October, 1928, pp. 446–455.)

The present Belin System transmits by the use of a photo-electric cell, controlling the amplitude of a current of musical note frequency; it receives by a photographic method, using a Blondel oscillograph: the recently resuscitated electro-chemical or purely mechanical methods being dismissed as "impracticable for commercial traffic." The article includes details of the apparatus and discusses synchronisation, amplifiers, bands of frequency and possible speeds under various conditions.

TELEVISION: PAST AND FUTURE.—A. A. Campbell Swinton. (*Discovery*, November, 1928, V, 9, pp. 337–339.)

Beginning with a brief historical outline, the writer points out that the "modern" revolving disc with staggered apertures was patented by Nipkow in 1884: mirrors on a rotating wheel were proposed in 1889, and rapidly vibrating mirrors were patented in 1897. Even the "scanning" of the object by a moving ray was patented by Ekstrom in 1910. He goes on to criticise severely the present achievements in the U.S. and England, and reverts to his advocacy of cathode ray methods proposed by himself twenty years ago.

TELEVISION APPARATUS.—G. Cristesco. (Roumanian Patent, published March, 1928.)

An outline of the multiple mirror arrangements mentioned in this patent is given in the *Rev. Gén. d. l'Élec.*, 10th November, 1928, p. 167D.

IMPROVEMENTS IN KERR CELLS.—(German Patent, 462,579, Karolus, published 14th July, 1928.)

The cell is placed not in a parallel ray but at the point of intersection of a convergent beam. Thus the condenser plates of the cell can be close together.

for increased sensitivity. To add to the effectiveness, the plates of the condenser are not flat but so shaped as to fit in with the convergent beam.

THE PHOTOELECTRIC LONG WAVE LIMIT OF POTASSIUM VAPOR: THE EMERGENT ENERGY OF PHOTOELECTRONS IN POTASSIUM VAPOR.—R. C. Williamson. (*Proc. Nat. Acad. Sci.*, October, 1928, V. 14, pp. 798–801.)

THE PHOTOELECTRIC EFFECT IN GLOW-DISCHARGE TUBES.—H. J. Reich. (*Journ. Opt. Soc. Am.*, October, 1928, Part 1, V. 17, pp. 271–288.)

Gas-filled glow-discharge tubes are coming into prominence in connection with rectification, voltage-regulation, television and other purposes. The present paper investigates a number of points, regarding the photoelectric effect, not satisfactorily dealt with before. The writer summarises his experimental results and conclusions thus: (1) The light effect is a true photoelectric effect produced by the presence of small amounts of alkali metals on the electrodes and walls. These experiments do not necessarily prove that the light effects observed by Oschwald and Tarrant and by Ryde were due to the same cause, but the probability is that the latter were similar to those here described. This question can be fully answered only after a thorough study of tubes made specially for the purpose (Ryde, in criticising the O. and T. conclusions, attributed the effect either to the presence of hydrogen or to a film on the surface of the electrodes). (2) When the tubes are used in an oscillating circuit, the reduction of sparking potential with illumination is not proportional to light intensity, the reduction per unit of intensity being less for high than for low intensities. (3) There is no definite relation between the portion of the tube illuminated and the magnitude of the effect. (4) In addition to the polarising action studied by Taylor, which tends to raise the sparking potential in successive discharges, there seems to be in this type of tube another action producing the opposite effect. (The type in question is filled with neon or helium at 1–5 mm. pressure with aluminium electrodes about 2 cm. apart.) (5) In tubes which have been used for quite a few hours, when the tube is oscillating at frequencies below about 45 cycles, an increase of intensity will—at certain intensities—produce an abrupt increase of sparking potential rather than the normal decrease. (6) The voltage-time wave form is not that which would be expected from theory. The terminal voltage does not fall according to an exponential function of the time during discharge, the rate of discharge suddenly dropping to a much lower value shortly before the extinction potential is reached. The time of discharge takes up more than half the complete cycle, instead of about 1 per cent. or less, as theoretically predicted and as observed in other types of tube. This points out the necessity of studying the wave form of any glow-discharge tube before applying theoretical equations to it, or before using it in obtaining a linear time axis in oscillograph work. (7) Discharge can be controlled by means of an external shield or grid connected to various parts of the circuit, either directly or through a high resistance. For a complete list of references covering the theory of the tube and its application in oscillograph work, the writer refers to the paper by Bedell and Reich, *Journ. Am. I.E.E.*, June, 1927.

FURTHER CONSIDERATION OF THE PHOTO-ELECTRIC PHENOMENON OF THE AUDION.—Q. Majorana. (*Nature*, 10th November, 1928, V. 122, p. 754, *résumé* from *Roy. Nat. Acad. Lincei*, 1st June.)

The effect considered is produced when an intermittent strong beam of light falls on an audion in which the wire leading to the grid is covered with a substance semi-conductive (cuprite, molybdenite, etc.), or electrolytically conductive (artificially prepared silver sulphide). It appears to be a perturbation, electrical in character, caused by the arrival of the light, but not corresponding with external liberation of electrons.

MEASUREMENTS AND STANDARDS.

EINE VEREINFACHTE SCHALTUNG FÜR DIE AUFNAHME VON RÖHRENKENNLINIEN (A Simplified Arrangement for Plotting Valve Characteristics).—L. Bergmann. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 129–131.)

A sliding resistance is described with two independent and separately-insulated sliders, which when connected as a potentiometer gives—with one battery only—two variable P.D.s. Its use for plotting valve characteristics greatly simplifies the usual process.

ANORDNUNG UND GERÄTE ZUR UNTERSUCHUNG VON HOCHFREQUENZVERSTÄRKERN (Arrangements and Apparatus for the Investigation of H.F. Amplifiers).—M.v. Ardenne. (*E.T.Z.* 15th November, 1928, pp. 1675–1678.)

The apparatus is distinguished by its comparatively easy construction and for the short time required for the measurements. The layout comprises the oscillator (mains-fed) fully screened: the wavemeter, a "dosing apparatus" by which the magnitude of the voltage handed on to the amplifier under tests is regulated; the amplifier itself; and the valve-voltmeter. Precautions as to screening, etc., are discussed. Diagrams of connections and photographs of the apparatus are given, and some specimen amplification curves.

STANDARD FREQUENCY TRANSMISSIONS BY THE BUREAU OF STANDARDS. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1300–1301.)

A new schedule of monthly transmissions of signals of standard frequencies, ranging from about 2,400 m. to 50 m. wavelength.

THE VIBRATIONS OF TUNING-FORKS.—E. A. Harrington. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 224–239.)

Author's abstract: The energy dissipated by frictional forces in a tuning-fork was studied by means of two electrically driven forks: (1) an ordinary fork, (2) a fork made by clamping two

steel bars with a rectangular block between them, in a vice so that very little energy was expended in moving the stand upon which the fork was mounted. The following properties were investigated: (1) the equivalent length of a rigid straight bar turning through the same angle as the tangent at the end of the prongs; (2) the relation between the current driving a fork and the deflections of the prongs produced, both for steady and resonant deflections; (3) the logarithmic decrement, and the effect on the logarithmic decrement of damping due to vanes at the end of the prongs; (4) the energy due to emission of sound. It was found that: (1) a straight bar about 73 per cent. of the whole length of the prong was approximately equal to the equivalent length; (2) the deflections of the prongs were proportional to the square of the current; (3) the change in the logarithmic decrement was roughly proportional to the area of the vanes; (4) about 3.5 per cent. of the total energy was converted into sound.

Über die vermittels einer Stimmgabel erregten Röhrenoszillatoren (Valve Oscillators driven by Tuning-fork).—Y. Watanabe. (*Zeitschr. f. Hochf. Tech.*, October, 1928, V. 32, pp. 116–121.)

Six types of valve circuit in which the reaction-coupling is provided by the vibrations of a tuning-fork are dealt with, in each case an equivalent purely electrical circuit being worked out by means of the (mutual and self) motional-impedance of the fork. The constants of the latter are determined by direct measurement of the induced E.M.F. by an A.C. potentiometer, and by an application of Rayleigh's theory. The properties of the various types of circuit are investigated, particularly their deviations from the natural frequencies of the forks, and the conditions for the production of oscillations. The types of circuit are: the simple circuit (Eccles, 1919); circuit with tuned grid; circuit with tuned grid and tuned anode; with grid transformer; with anode and grid transformers; circuit with combined electrical and mechanical reaction.

Determination of the Axes of Piezo Crystals.—(German Patent 461,497, Giebe and Scheibe, published 26th June, 1928.)

The optical axis is easily found and a plate is cut from the crystal perpendicular to this axis. A ring is cut from the plate, a mark being made before cutting to indicate the natural position of ring in plate. The ring is excited by a uniformly radial A.C. field from suitably shaped electrodes, so that three complete wavelengths are distributed along the circumference. Observed in a low-pressure atmosphere, luminous effects show the positions of the three electrical axes, and by the relative positions of these and of the indicator mark, the axes of the crystal itself are found.

Dynamic Study of Magnetostriction.—K. C. Black. (*Proc. Am. Academy*, April, 1928, V. 63.2, pp. 49–66.)

Work done after Pierce's application of the phenomenon to oscillators (November, 1928, Abstracts). With maximum resonance the amplitude of vibration may be 200 times as great as the length change in a steady field. (*Cf.* van Dyke, these Abstracts, 1928, p. 526: resonance in piezo-electric circuits magnified the effect "several thousandfold.")

A Visual Method for Studying Modes of Vibration of Quartz Plates.—A. M. Skellett. (*Journ. Opt. Soc. Am.*, October, 1928, Part I, V. 17, pp. 308–317.)

Photographs are shown of a number of patterns on the surface of a quartz plate formed by the glow discharge at low pressures of gas (Argon at about 5 mm.), at various radio frequencies of the exciting oscillator. Evidence is presented in support of the theory that the bright spots occur at the antinodes of standing waves; from which it appears that the value of Young's Modulus is the same for directions at angles from 0 to 78 deg. from the optic axis. Measurements of the distances between antinodal rows give wavelengths which agree, within less than 1 per cent., with wavemetre values of the oscillator; except in rare cases where the disagreement is 20 or 30 per cent., and it is supposed that the pattern is a part only of some larger pattern.

Sections in any direction in the crystals may have longitudinal standing waves set up in them, the lengths being such that there is either a node or an antinode at each end. Water vapour is found to condense on the crystal in the configuration of the pattern last formed. When the voltage was cut down to the threshold value for ionising the gas by crystal vibration, a thin momentary spark would sometimes jump between the electrodes close to the surface of the crystal, taking not the shortest route (10 mm.) but one varying in length up to 13 mm., and only occurring when the plate was oscillating so as to produce a pattern.

A New Method for Determining the Efficiency of Vacuum-tube Circuits.—A. Crossley and R. M. Page. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1375–1383.)

The writers point out the deficiencies of the two usual methods, the circuit resistance variation method and the optical pyrometer method gauging the temperature of the plate by its colour, more especially for measurements in the high-frequency band. They go on to describe a quick method reliable for any frequency-range, depending on the use of a Cambridge surface pyrometer (designed primarily to measure the temperature of rolls, etc., in the manufacture of paper, textile materials, etc., and comprising a flat strip thermocouple specially mounted, and a millivoltmeter). Readings are taken of the temperature of the valve-walls when the circuit is oscillating. The oscillation is then stopped and the plate input watts altered until the identical pyrometer reading is obtained. The difference in watts represents the radio-frequency output power. Examples are given of tests on crystal-controlled oscillators (where it was shown definitely that the output obtained with a push-pull circuit was double that of a single valve circuit): 250 W. shield-grid amplifier valves (the 3-electrode valve is a more efficient amplifier—on about 70 metres—than the shield-grid valve; greater

efficiency is obtainable with greater excitation voltage to the grid), and on aerial resistance. Examples on this last measurement show fairly consistent results, seven tests spread over ten days and with varying outputs giving an average of 51.3 ohms with extreme values of 45.5 and 56.1.

A General Theorem on Screened Impedance.—R. M. Wilmotte. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 788–795.)

The theorem leads to the fact that the impedance of any piece of screened apparatus can be given without stating which terminal should be kept at the potential of the screen, provided that one of the two terminals is so kept at the potential of the screen, but without connection to it. Certain limitations are discussed.

The Errors associated with High Resistances in Alternating Current Measurements.—R. Davis. (*Journ. Sci. Inst.*, October, 1928, V. 5, pp. 305–312.)

First part of a paper dealing with the properties of high resistances for use in electrical measurements at high voltages. In the case of a resistor having a resistance of 600,000 ohms, used for voltage transformer measurements, the capacity to earth of the windings was estimated to be of the order of 300$\mu\mu$F., large enough to cause a serious error, if not corrected for, in the determination of phase angle, etc. The paper considers one section of a resistor together with its shield. The effect of the screen potential on the phase angle at a point in the section is determined: the effect of adding units in series is considered and expressions are derived for the phase angle at the low and high voltage ends of the resistor. A method for determining the characteristics of a unit is described. Some of the practical limitations which may manifest themselves in the designing of a shielded resistor are discussed.

A Gang Capacitor Testing Device.—V. M. Graham. (*Proc. Inst. Rad. Eng.*, October 1928, V. 16, pp. 1401–1403.)

Testing equipment for a gang condenser system must be simple, accurate and reliable. The test described uses two oscillating circuits and the zero beat method of measurement. The complete procedure is described.

Useful Data Charts (No. 15). Efficiency of Coupling by Grid Leak and Condenser.—R. T. Beatty. (*Wireless World*, 7th November, 1928, V. 23, pp. 648–649.)

One of a series of articles and Abacs for solving practical problems, the first of which appeared in the issue for 11th July, 1928.

Simple Inductance Formulas for Radio Coils.—H. A. Wheeler. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1398–1400.)

On the same pattern as the Hazeltine formula for the inductance of a multi-layer coil ($L = 0.8\ a^2n^2/(6a + 9b + 10c)$ microhenrys, where a = radius to mid-point, b = axial thickness, c = radial thickness, all in inches) the writer gives two easily remembered and accurate formulæ for single layer coils: $L = a^2n^2/(9a + 10b)$ and $L = a^2n^2/(8a + 11b)$, the former to be used when $b > a$, the latter when $a > b$. When the coil is a single layer spiral, the second formula is applicable in the form $L = a^2n^2/(8a + 11c)$.

Die Messungen des Widerstandes von Antennenseilen bei hohen Frequenzen (The Measurement of the Resistance of Stranded Aerial Wire at High Frequencies).—W. P. Jakowleff. (*Zeitschr. f. Fernmeldetech.*, 31st May, 1928, pp. 76–77.)

An experimental comparison between metre lengths of stranded wire and solid conductors of the same cross-section, to determine the effect of the contact resistance opposing the passage of current from one strand to another. The writer concludes that while at low frequencies the stranded wire has less resistance than the solid, for thick wires the two values become equal at $\lambda = 4{,}000$ m., for thin wires at $\lambda = 110$ m. Above those frequencies the solid wire has the smaller resistance. A composite wire of parallel strands is also compared.

Messung von Antennenwiderständen (Measurement of Aerial Resistance).—W. P. Jakowleff. (*Zeitschr. f. Fernmeldetech.*, 31st May, 1928, pp. 78–79.)

Description of a simple " Antenna-ohmmeter " for quick and accurate measurements, based on Pauli's method.

An Ampere Meter for measuring Alternating Currents of Very High Frequency.—E. B. Moullin. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121 A., pp. 41–71.)

A long paper on the author's new type of ammeter to carry, unshunted, currents up to several hundred amperes at frequencies up to 30 megacycles, and with a frequency-correction which can be calculated (*cf.* Abstracts, 1928, p. 467). He describes very fully the conception, analysis and constructional development of the instrument, and outlines a modified form for large currents which would result in reducing the inductance. In the example taken of this modified form the power absorbed by 100A at 2.5 megacycles would be of the order of half a watt.

The Vibration Galvanometer observed Stroboscopically.—J. B. Saunders. (*Journ. Opt. Soc. Am.*, October, 1928, Part I, V. 17, pp. 326–327.)

When such a galvanometer is being used in the null method, its indications of unbalance do not tell whether the settings are too high or too low, both cases giving a hazy broadened image. Stroboscopic methods, either with sector disc or neon lamp, clear up this ambiguity.

Long Period Moving Coil Galvanometers.—C. V. Drysdale. (*Journ. Sci. Inst.*, October, 1928, V. 5, p. 330.)

A letter referring to D. C. Gall's article (see Abstracts, 1928, p. 644) and pointing out the possible

great use of the principle for the measurement of very low P.D.s where the resistance of the galvanometer should be very low; which is impossible in the ordinary sensitive moving-coil galvanometer as the fine suspensions alone may have a resistance of some ohms. But if a thick suspension could be used and the major portion of the control counteracted by counter-magnetism, the low-resistance moving-coil galvanometer would become a possibility.

LOUD SPEAKERS: RECENT WORK ON. (See Trendelenburg's article under "Acoustics and Audio Frequencies.")

SUBSIDIARY APPARATUS.

DER KATHODENSTRAHL-OSCILLOGRAPH ALS REGISTRIERINSTRUMENT, SPEZIEL FÜR RASCHVERLAUFENDE VORGÄNGE (The Cathode-ray Oscillograph as a Registering Instrument, especially for rapidly occurring Processes). —K. Berger. (*Bull. d. l'Assoc. Suisse d. Élec.*, 5th November, 1928, pp. 688–694.)

A supplement to the former paper (Abstracts, 1928, p. 525); the special discharge tube and roll film attachment here described, combined with the method of ray deviation discussed in the former paper, complete an apparatus which is suitable for recording atmospheric disturbances or the phenomena of super-tensions in electrical installations. The roll-film gives 300 oscillograms for one vacuum. Specimen records are shown.

OSRAM-HOCHSPANNUNGS-GLIMMLAMPE (Osram High Voltage Glow Lamp).—(*E.T.Z.*, 1st November, 1928, p. 1616.)

This lamp works on voltages up to 1,500 V. It shows a weak light even down to 200 V., and can thus be used as a voltage indicator or measurer, the brightness of the light indicating the voltage.

DIE DEUTSCHE RAYTHEON-RÖHRE (The German Raytheon Valve).—H. Simon and M. Bareiss. (*E.T.Z.*, 1st November, 1928, pp. 1604–1606.)

The two-phase blue-glow rectifier valve developed by the Osram Company is described and illustrated, the return current curves for new and long-used valves are given, together with curves showing the variation of D.C. output voltage with applied A.C. voltage, for 20 and 100 mA. outputs: current-voltage curves; and wave-form curves. Advantages of this form of rectifier over other valve rectifiers (high vacuum: gas-filled hot cathode types) are mentioned, in regard to the absence of a heating winding for the transformer, and to the possibilities of mass production of uniform and long-lived valves.

A GOVERNOR FOR H.F. MACHINES.—(German Patent 461,905, Lorenz, published 2nd July, 1928.)

A disc rotating in a vertical plane carries near its edge the fixed end of a strip-spring lying along an arc, and weighted at a spot near the radius normal to the spring. When this weight moves towards the edge, a contact is closed. When the disc is in such a position that the weight is at the bottom, centrifugal force and gravity are working together to close the contact: when the weight is at the top, gravity opposes the centrifugal force and tends to open the contact. Thus the duration of contact—and therefore the value of the regulating current—is dependent on the number of revolutions per second.

MAINS TRANSFORMER DESIGN: A NEW METHOD OF DESIGN BASED ON ASSUMED DIMENSIONS OF THE IRON CORE: PROCEDURE FOR DETERMINING THE ACTUAL LOSSES IN TRANSFORMERS.—H. B. Dent. (*Wireless World*, 24th October and 7th November, 1928, V. 23, pp. 569–572 and 630–632.)

ÜBER DEN ZUSAMMENHANG ZWISCHEN KORNGRÖSSE UND MAGNETISCHEN EIGENSCHAFTEN BEI REINEM EISEN (The Relation between Grain Size and Magnetic Properties of Pure Iron).—G. T. Sizoo. (*Zeitschr. f. Phys.*, 27th October, 1928, V. 51, pp. 557–564.)

Coercive force and hysteresis work decrease, maximal permeability increases, as crystal-size increases. Remanence, electrical resistance and temperature coefficient are all independent of the size.

MAGNETISCHE HYSTERESIS BEI HOHER FREQUENZ (Magnetic Hysteresis at High Frequencies). —W. Neumann. (*Zeitschr. f. Phys.*, 18th October, 1928, V. 51, pp. 355–373.)

Swedish ribbon-steel and 50 per cent. Fe-Ni alloy are investigated at frequencies up to 2,550 p.p.s.

STATIONS, DESIGN AND OPERATION.

SINGLE WAVELENGTH WORKING: PREVENTION OF INTERFERENCE. (German Patent 462,905, Lorenz, published 21st July, 1928.)

When several transmitters on the same wavelength are controlled by one central station, certain localities suffer from bad reception owing to interference between the various incoming waves. According to the invention, this is remedied by imposing on one or more of the transmitters periodic variations of frequency, phase or amplitude, which follow on one another so rapidly that they do not spoil reception.

RADIOTELEGRAPHIC CENTRE AT ROME (SAN PAOLO). G. Pession and G. Montefinale. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1404–1421.)

The old 250 kW. Poulsen arc (10,750 m.) had a maximum range of 4,500 km. The station now has a 15 kW. valve transmitter using 34 m., a 6 kW. set using various waves, 32–106 m., and a 15 kW. medium wave set (2,250–4,800 m.) for communication with the Mediterranean Sea Stations. The 34 m. wave set gives a 12 hr. continuous winter service with the Far East, an 18 hr. service with Somaliland and practically continuous service with the Dodecanese and the N. African Colonies. It has not been found possible to eliminate the silent zone on the 34 m. wave at short distances from the station. A Beverage aerial is used for reception.

It is stated that after testing various types of receiving sets it was found that the superheterodyne

circuit was the best. "For practical purposes, however, a simplified receiver with a regenerative valve in series with an audio-frequency stage through an audio-frequency filter and two stages of amplification was preferred." This set utilised a Wheatstone recorder. In the transmitter, rather serious variations of frequency were found to be greatly dependent on variations of filament voltage. A separate voltage regulator was therefore used for each set. Various forms of transmitting aerial were tried for the short waves, including the old 0.011 mfd. fan-form aerial with a natural wave-length of 3,500 m., and a horizontal aerial 5 m. above the ground. Results were indefinite, one aerial appearing about as good as another.

DIE EUROPÄISCHEN RUNDFUNKSENDER (European Broadcasting Stations). (*E.T.Z.*, 11th October, 1928, p. 1513.)

A list with names, sometimes call-letters, frequencies, wavelengths and powers; and a second list showing the total number of (licensed ?) listeners-in in each country and also the proportion per 1,000 of population, for 1927 and 1928. Denmark and Great Britain head this list with 57 per 1,000, Sweden coming near with 54.7; Germany has only 32.5. France is not given, though France and Sweden possess most stations in proportion to their size and population.

SOME STUDIES OF RADIO BROADCAST COVERAGE IN THE MIDDLE WEST.—C. M. Jansky, Jr. (*Proc. Inst. Rad. Eng.*, October, 1928, V.16, pp. 1356–1367.)

Studies of the field intensities produced by broadcasting stations throughout the States of N. and S. Dakota and Minnesota. The determination of the service area of a broadcasting station on the basis of the field intensities produced throughout the territory involves, among other things, the establishment of a ratio of field intensity to static and interfering intensities which may be considered as determining the border line between satisfactory and unsatisfactory reception. It is also necessary to establish a standard of reliability which can be considered satisfactory. The paper is too short to deal with these points systematically, and is best abstracted by giving some of the most pertinent conclusions. With daylight field intensities of 100 microvolts per metre, the rural or small town listeners feel they are receiving *good* broadcast service; with 50 μV/m, *fair* service; though these values are far lower than would be satisfactory for thickly populated districts where interference from non-radio devices and other sources are more serious. In the region under consideration, not more than 40 per cent. of the sets come within the "good" range of any station. Daylight distribution and signal intensity charts for a few stations are here given, and a map of the distribution of receiving sets showing numbers of rural and urban listeners. A similar map gives the "saturation factor" (ratio of number of sets to number of families, expressed as a percentage), which shows that there is no apparent relationship between such factors and the daylight intensities. The conclusion is that the factor depends rather on the *need* for broadcast service, and that night-time reception is all that the majority of listeners can depend upon. Night-time reception and fading are touched on, and charts for fading on 300–400 m. waves are given. When the more serious limitations imposed by heterodyne interference and lack of power have been removed, fading will probably be the most serious trouble for night service. Failing the ideal plan of utilising a given channel by operating a sufficiently large number of synchronised stations scattered throughout the entire nation, all carrying the same programme, the author advocates the same idea on a localised scale.

GENERAL PHYSICAL ARTICLES.

THE PHYSICS OF THE UNIVERSE.—J. Jeans. (*Nature*, 3rd November, 1928, V. 122, pp. 689–700.)

The first Wills Memorial Lecture of the University of Bristol. The review of recent additions to our knowledge leads up to an exposition of the lecturer's belief as to the ultimate fate of the universe. "There can be no creation of matter out of radiation, and no reconstruction of radioactive atoms which have once broken up. The fabric of the universe weathers, crumbles, and dissolves with age, and no restoration or reconstruction is possible. The second law of thermodynamics compels the material universe to move ever in the same direction along the same road, a road which ends only in death and annihilation." (*Cf.* Millikan and Cameron, Abstracts, 1928, p. 691; whose contrary theories are referred to and rejected in the present lecture.)

THE COSMIC RAYS. (*Nature*, 10th November, 1928, V. 122, p. 746.)

Deals with Millikan and Cameron's paper in the October, 1928, *Physical Review* (Abstracts, 1928, p. 691). The writer concludes "It is noticeable that Professor Millikan and Dr. Cameron do not consider here why the most favoured condensations of protons and electrons should be those which go to build up the few nuclei which are actually found to constitute the greater part of ponderable matter."

EXPERIMENTS ON SUPRACONDUCTORS.—W. J. de Haas. (*Elec. Review*, 21st September, 1928, V. 103, p. 497.)

Abstract of paper read at the last British Association Meeting.

EVIDENCE OF THE PRESENCE OF PROTONS IN METALS.—A. Coehn. (*Journ. Franklin Inst.*, November, 1928, V. 206, p. 674.)

Summarised description of an experiment in which hydrogen, diffused in a palladium wire, is shown to yield protons which can be driven backwards and forwards along the wire by an electric current.

ELECTRIC CONDUCTIVITY AND OPTICAL ABSORPTION OF METALS.—E. H. Hall. (*Proc. Nat. Acad. Sci.*, October, 1928, V. 14, pp. 802–811.)

The known facts of the optical behaviour of metals are used to condemn both the Lorentz and the Sommerfeld Theories of Conduction; whereas they fit in with the writer's "dual" theory—that the current is maintained in part by free electrons sharing the energy of heat agitation, but mainly by an interchange of electrons in encounters between atoms and positive ions.

La Cristallisation des Substances Mésomorphes dans le Champ Magnétique. Obtention d'un Solide à Molécules Orientées (Crystallisation of mesomorphic Substances in a Magnetic Field; the obtaining of a Solid with oriented Molecules).—G. Foëx. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 822–823.)

A special process is described which prevents the orientation being lost as the substance crystallises out. *Cf.* Cabannes, Abstracts, 1928, p. 691.

On the Penetration of an Electric Field through Wire-gauze.—W. B. Morton. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 795–801.)

Results of various workers in investigating mobilities of gaseous ions have differed rather widely, and one suggested cause of error is that the steady electric field used for pushing the ions through the partition of wire gauze, and the alternating field on the other side of the gauze, interpenetrate each other through the meshes. The present note examines such inter-penetration as a mathematical problem, to find an upper limit to this source of error. The conclusion is that the effect only changes the travel of the ion by an amount comparable with the spacing of the gauze; so that inter-penetration of the fields seems to be an unimportant cause of error.

Some Remarks concerning the Production and Absorption of Soft X-Rays and Secondary Electrons.—E. Rudberg. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121, A., pp. 421–432.)

The writer estimates the efficiency of the production of photoelectrons from metals by soft X-rays. No suggestion is made as to the nature of the process by which part of the energy of the primary electron would be transferred to a free electron of the conductor, but the writer refers to a paper by O. W. Richardson (Abstracts, 1928, p. 525), according to which this transfer involves the interaction of radiation. It seems that the adoption of this view will remove the most obstinate difficulties of the auto-photoelectric theory of thermionic emission and chemical reactions in general.

Theorie der Beugung von Electronen an Kristallen (Theory of the Diffraction of Electrons at Crystal Surfaces).—H. Bethe. (*Ann. d. Physik*, 5th October, 1928, No. 1, V. 87, pp. 55–129.)

Über die senkrechte Ablenkung langsamer Elektronen an Gasmolekülen (The Deflection at Right Angles of Slow Electrons by Gas Molecules).—R. Kollath. (*Ann. d. Physik*, 5th October, 1928, V. 87, No. 2, pp. 259–284.)

MISCELLANEOUS.

Method for Discovering Leaks in Glass Vacuum Apparatus.—P. Selényi. (*Zeitschr. f. Phys.*, No. 9/10, 1928, pp. 733–734.)

A method depending on the different coloured glows produced by Tesla currents in CO_2 and air. Thus if the vacuum apparatus contains air at low pressure and a current of CO_2 is passed over the suspected portions of the exterior, the glow produced by Tesla currents changes at the leaks from the red glow of the air to the bluish-white glow of the CO_2.

Conference of Australian Physicists at Canberra. (*Nature*, 10th November, 1928, V. 122, p. 747.)

Among other speakers, Professors Madsen and Laby contributed to a discussion on radio research in Australia; emphasis was laid on the need for pure research, and the suggestion was made that some fraction of the broadcasting revenue of a quarter of a million sterling should be set aside for this purpose. Dr. Beiler described the methods of prospecting now being tested in the field in Australia. Major Booth discussed the seismic method and described experiments on earth waves detected with a modification of the Tucker microphone.

Heating, Volatilisation and Atomisation by Heavy Electric Currents. (*Engineering*, 26th October, 1928, V. 126, p. 542.)

Summary of a Tokio paper entitled "Electric Explosions." The discharge from a condenser charged to 40 kV. was passed through wires of various materials and threads of mercury. Currents of 10^6 amperes per sq. cm. were used in some cases where the wires were kept under oil. In these latter experiments the transmutation of the metal was looked for but without success.

Secrecy in Radio Telephony. (*Scient. American*, June, 1928, p. 545.)

Photograph of part of a device which converts the speech at the transmitter into gibberish which is translated at the receiver. Demonstrated before the Engineers' Society.

Electrical Prospecting.—J. J. Jakosky. (*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1305–1355.)

Of the various types of electrical methods, some of which utilise natural earth currents, others direct or A.C. applied earth currents, and still others electromagnetic induction, the last has at present the widest application and is the one dealt with in this paper. The scope of the paper is indicated by some of the sub-headings: the Occurrence of Ores; Field of Application for the Electrical Methods (generally speaking, the difference in conductivity between the mineralised area and the surrounding envelope should be at least 100 to 1: it is often as much as 1,000 or even 10,000 to 1); Magnitude of Induced Voltage; Factors Affecting Current Flow; Impedance of Disseminated Ores; Impedance of Faulted Zones; Detection of Current Flow in a Conductor (direction-finding coil is best); "Sharpness" of Maxima and Minima; Operating Conditions; Effects of Phase Shift between Primary and Secondary Fields; Relationships between Depth and Length of Ore-body; Length of Ore-body (the change in energising frequency from low—1,000—to high—50,000 cycles or more—furnishes considerable information as to the structure of the body); Determining Depth of Conductor by Curve; Field Procedure during Detailed Survey;

Distortion of Primary and Secondary Fields; Phantom Dips; Effects of Frequency; Description of Energising Apparatus; Direction-finding Apparatus; Field Operating Conditions; Personnel of Crews; Interpretation of Field Data; Corrections for Topography and Dipping Conductor.

GEOPHYSICAL PROSPECTING.—A. S. Eve and D. A. Keys. (*Scient. American*, June, 1928, pp. 508–511 and 561.)

Reprinted from the Bureau of Mines paper referred to in Abstracts, 1928, p. 528.

GEOPHYSICAL EXPLORATION. (*Engineer*, 2nd November, 1928, V. 146, p. 487.)

A paragraph on the reported application by the American petroleum industry for licences for a number of short-wave transmitters. The method used for locating oilfields is to measure the lag between sound transmission and wireless: the velocity of the sound waves being affected by the presence or absence of salt formations which generally accompany oil deposits.

ELECTRIC ORE AND OIL DIVINING. (*Electrician*, 9th November, 1928, V. 101, p. 515.)

A paragraph dealing with the work now being done by about forty Swedish engineers, geologists, and their working crews, in different parts of the world, in locating "magnetic (*sic*) ore and oil deposits by means of a Swedish invention, the electrical prospector"; invented by Landberg and Sundberg, who were awarded the gold medal of the Royal Swedish Academy of Engineering Science. The method appears to be a resistance method, and it has successfully worked on copper and on oil deposits. No details are here given.

CONTINENTAL DRIFT.—A. Holmes. (*Nature*, 22nd September, 1928, V. 122, pp. 431–433.)

A review of a "symposium on the origin and movement of land masses, both inter-continental and intra-continental, as proposed by Alfred Wegener." (*See also* J. Vivié, Abstracts, 1928, p. 590.)

A SUGGESTED EXPLANATION OF THE CRYSTAL DETECTOR: RECTIFICATION PHENOMENA MAY BE TRACED TO PIEZO-ELECTRIC ACTION.—F. Regler. (*Wireless World*, 7th November, 1928, V. 23, p. 629.)

Summary of Regler's theory of the contact detector, from the *Physikalische Zeitschrift*.

LUMINOUS CARBORUNDUM DETECTOR AND DETECTION EFFECT AND OSCILLATIONS WITH CRYSTALS.—O. V. Lossev. (*Phil. Mag.*, November, 1928, V. 6, No. 39, pp. 1024–1044.)

Two types of luminescence, I and II, occur at a carborundum-steel-wire contact on the passing of suitable currents. Type I has a greenish-blue colour which is constant. Type II changes from orange to violet with change of P.D. from 6 to 28 V. (taking one crystal as an example—other crystals, or even other points on the same crystal, show corresponding but different changes). Rectification takes place in the same direction as that which increases Type I, but in the opposite to that which increases Type II. It is concluded that the unilateral conductivity of the carborundum contact is closely connected with its luminescence, and that the latter is a consequence of a process very similar to the cold electronic discharge. The carborundum substance does not produce thermoluminescence, hence the cause of the luminescence is *not* a Joule effect at the contact: only the colour change of Type II is due to the Joule effect on the fluorescence produced by the luminescence. The inertia both of beginning and cessation of luminescence is very small, hence the phenomenon can be used as a Light relay. Frequencies up to 78,500 p.p.s. do not blur the flashes. The brightness can be made enough to record perfectly an A.C. of about 500 p.p.s. on a moving photographic plate. The R.M.S. value of the current here used was 0.24 A. The paper deals also with the use of oscillating crystals, particularly zincite, for reception of short waves down to 24.3 m.

BROADCASTING BY WIRED WIRELESS: THE UNDERLYING PRINCIPLES OF THE SYSTEM FULLY EXPLAINED: METHODS OF DISTRIBUTING SIGNALS TO SUBSCRIBERS' LINES.—O. F. B. (*Wireless World*, 14th and 21st November, 1928, V. 23, pp. 677–679 and 698–700.)

Although "carrier" systems for extending the use of existing telephone circuits, and also for communication and control along high voltage power lines, are being used a good deal in America and Central Europe, their use for broadcasting has been limited to a few isolated experiments. But the Western Electric Co., of America, have worked out in detail, and patented, a complete system for the purpose. In view of the increasingly overcrowded state of the ether, the writer suggests that wired-wireless may later become a useful adjunct to ordinary broadcasting. After a general consideration of the problem, the paper discusses the patented system named above.

EIN NEUES SYSTEM FÜR WECHSELSTROMMEHRFACHTELEGRAPHIE (A new System for Multiplex A.C. Telegraphy).—M. Wald. (*E.N.T.*, October, 1928, V. 5, pp. 391–398.)

The system has been tested in Austria and is being adopted by the Administration of Telegraphs. For ordinary speeds (Hughes' apparatus) a difference of 50–60 cycles between two adjacent carrier-frequencies is enough, so that in the band of about 1,900 cycles available in Pupinised cables, about thirty separate frequencies can be utilised. For higher speeds the gap need only be increased to an unimportant extent.

DIE KETTENLEITER IN DER UNTERLAGERUNGSTELEGRAPHIE (Filter Chains in Telegraphy imposed on Telephone Lines).—Ch. Wisspeintner. (*E.N.T.*, October, 1928, V. 5, pp. 382–390.)

Multiplex A.C. telegraphy uses the frequency-zone employed in speech. For imposing telegraphic communication on telephone lines, on the other hand, frequencies from 0 to 50 cycles per sec. are used, in the so-called "under-imposing" (unterlagerungs) telegraphy. The paper deals with such a system in general, and in particular with the requirements and values of the necessary filters.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

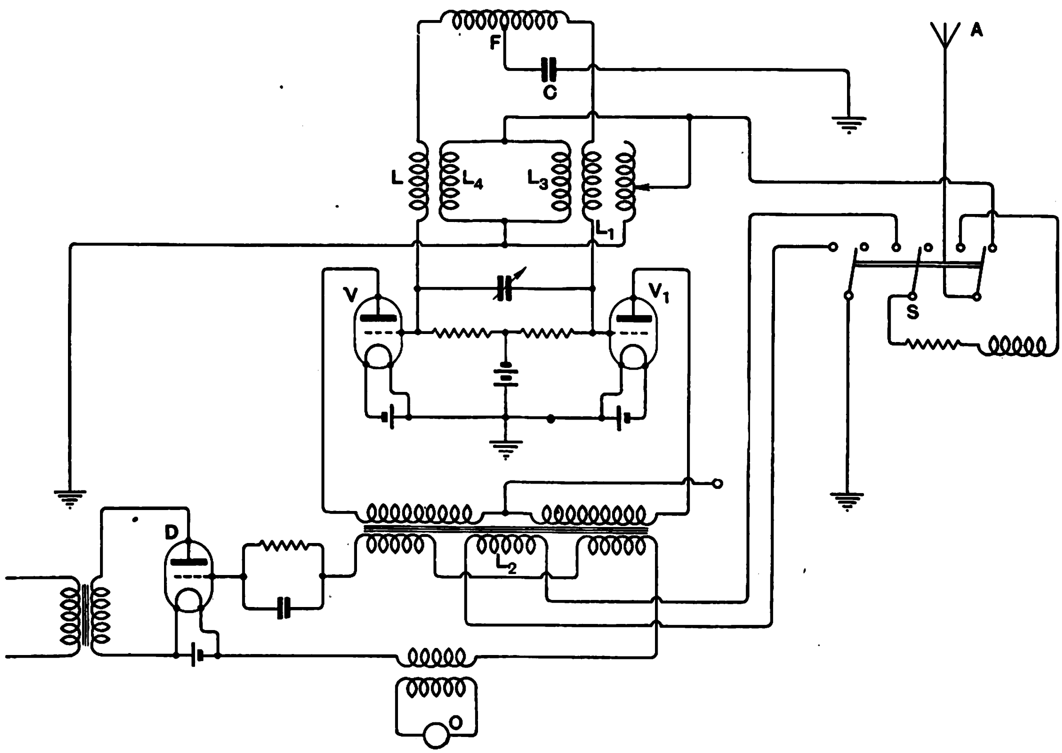
DIRECTION-FINDING.

(*Convention date* (*U.S.A.*), *29th April*, 1927. *No.* 289490.)

When a rotating-loop D.F. installation is used aboard a ship, the presence of metallic structures such as iron masts, funnels, stays, etc. induces out-of-phase voltages in the receiving-aerial which tend to blur the sharpness of definition of the critical maximum and minimum points. This effecti s to be distinguished from the so-called quadrantal error, which is due to in-phase induction, and causes a distortion of the incoming wave-front.

received on the aerial A is fe d to a coil L_2 couple to the output from the valves V, V_1, which feed the detector D of a superheterodyne receiver supplied with local oscillations from a source O. This serves to remove the "sense of direction" ambiguity. In the right-hand position of the switch S, the pick-up from the aerial A is fed to coils L_3, L_4, the coupling of which with the input coils L, L_1 is then so adjusted as to compensate for any lack of definition in the "bearing" readings due to mast effect.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.



The Figure shows an installation in which provision is made to correct for the above-mentioned "mast effect," and also to remove the well-known 180° "sense" ambiguity. The directional frame-aerial F is earthed at its mid-point through a condenser C, and is connected through coils L, L_1 to two push-pull valves V, V_1. A non-directional aerial A is also connected through a switch S to the valve circuits.

In the left-hand position of the switch S, energy

TELEVISION APPARATUS.

(*Application date*, *17th June*, 1927. *No.* 297152.)

A combined telephony and television system is so arranged that a person A at one end of the line is not only able to see the distant person B to whom he is speaking, but is himself "scanned" by local apparatus so that his image is transmitted to the distant end of the line. As the subscriber A speaks into his microphone, his features are framed

vibration. During this time the grid bias applied to the valves V_1, V_2 will be such as to cause a definite value of current to flow through a damping coil D. Should any frequency "drift" occur in the fork, the "coincidence" interval of the contacts K_1, K_2 will vary. The discharging action of the condenser C then modifies the average grid-bias applied to the valve V_1, and the current in the damping or control coil D is corrected accordingly. A second damping coil D_1 may be provided as shown.

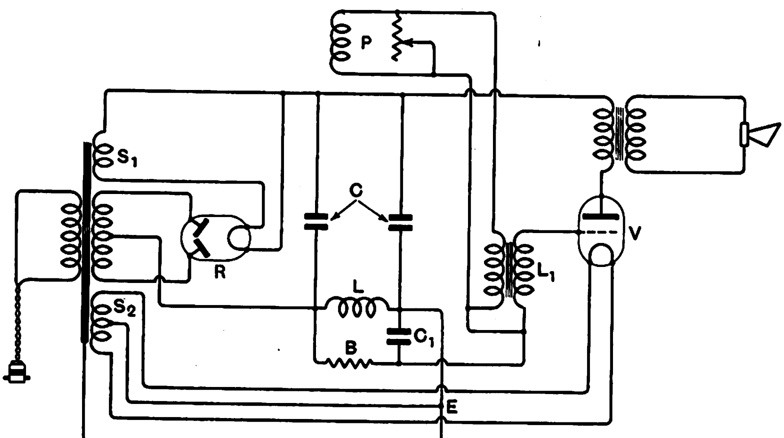
Patent issued to J. A. Smale.

BIASING POWER-AMPLIFIERS.

(*Convention date* (*U.S.A.*), *22nd July*, 1927. *No*. 294250.)

In order to economise power and save voltage-drop, grid bias is derived from one of the impedances in the smoothing-circuit of the eliminator unit, instead of being tapped off from a resistance shunted directly across the plate and filament of the valve as usual. The figure shows an amplifier valve V feeding a loud speaker from an electric pick-up P.

The plate supply is taken from a full-wave rectifier, whilst the filaments of both amplifier V and rectifier R are heated by AC current from the secondaries S_1, S_2. The usual smoothing-circuit is shown at L, C. It will be seen that the secondary S_2 is earthed, as is also one end of the filter inductance L, the latter being shunted by a resistance B and a condenser C_1. The grid-filament circuit therefore comprises the input coil L_1, resistance B, and inductance L to earth. The normal current



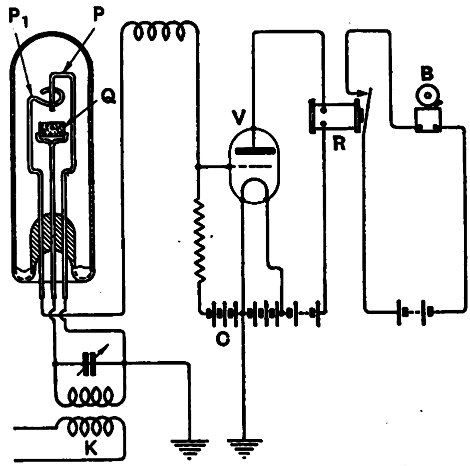
flowing through the coil L accordingly produces a voltage drop across its ends which serves to bias the grid.

Patent issued to The British Thomson Houston Co., Ltd.

SELECTIVE PIEZO-ELECTRIC DEVICES.

(*Convention date* (*U.S.A.*), *3rd January*, 1927. *No*. 283113.)

It is known that if a piezo-electric crystal is immersed in an atmosphere of neon, argon, or other readily-ionised gas at low pressure, a glow occurs when oscillations of fundamental frequency are applied across the crystal. Simultaneously owing



to ionisation the surrounding gas becomes conducting. This effect is utilised to secure a highly-sensitive indication of an applied frequency change.

A crystal of quartz Q is mounted in a glass bulb in close proximity to an electrode P. A second electrode P_1 is coiled closely around the first but without actually touching it. A connection is taken from the electrode P_1 to the grid of an amplifier, in the output current of which is a relay R operating an alarm bell B or other signal. Normally a paralysing bias is applied to the grid of the amplifier from a battery C.

When the frequency in the circuit K reaches a certain critical value, the piezo crystal Q glows, and the air inside the bulb is rendered conductive. This in effect connects the electrode P_1 to the electrode P, and so opens a relief path to ground for the negative charge on the grid of the amplifier V. The relay R thereupon sounds the alarm B.

Patent issued to the Metropolitan Vickers Electrical Co., Ltd.

A MAINS-FED VALVE.

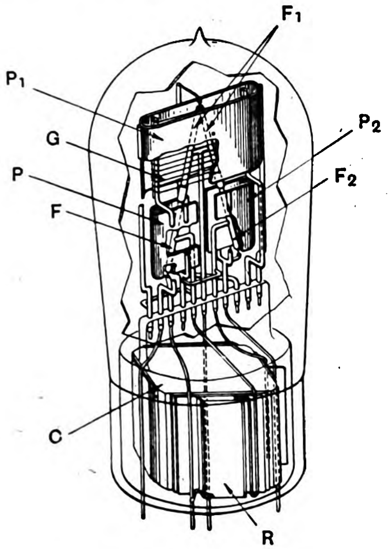
(*Application date*, *21st July*, 1927. *No*. 298296.)

Relates to a self-contained valve which is intended to be supplied directly from alternating-current mains. It comprises a rectifier-unit, and a

current-limiting or smoothing device for supplying rectified current to the plate, together with a special smoothing-condenser and voltage-reducing resistance, all housed inside the same glass bulb.

The V-shaped cathode is divided into three parts F, F_1, F_2, of which the upper part F_1 co-operates with a grid G and plate P_1 to form an amplifying unit, whilst the two lower portions F and F_2 co-operate with plates P and P_2, which serve as current-limiting and rectifying devices respectively.

The filament consists of a spiral wire of suitable resistance to take the full mains-voltage. The wire is surrounded first by a quartz tube and then by a tube of nickel or tungsten coated with electron-emitting oxides of barium, thorium, etc. A smoothing-condenser C is housed inside the turned-up lower flange of the glass tube. The raw AC supply current is first rectified across the filament section F_2 and plate P_2 and then passes to the unit, F, P,



the saturation effect of which acts as a limiter or smoother. The output from the latter is fed to a resistance R from which the rectified voltage to the amplifier plate P_1 is tapped off.

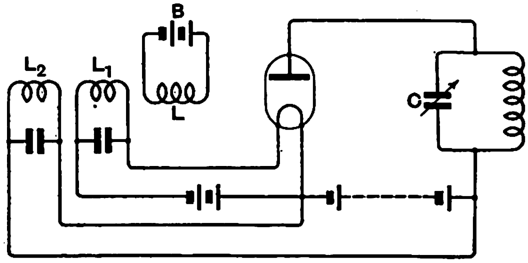
Patent issued to A. Mavrogenis.

CONSTANT-FREQUENCY OSCILLATORS.

(*Convention date* (*Germany*), *24th June*, 1927. *No.* 292584.)

In the Habann type of valve generator, a negative-resistance effect is produced by the action of an electromagnetic and electrostatic field applied mutually at right-angles across the path of the electron stream inside the tube. The resultant frequency of the generated oscillations tend to vary with fluctuations in the filament and plate voltages, or with the source of supply of the auxiliary magnetic field.

The invention consists in balancing-out any such fortuitous fluctuations and so maintaining an output of unvarying frequency. As shown in the Figure, the auxiliary magnetic field is provided



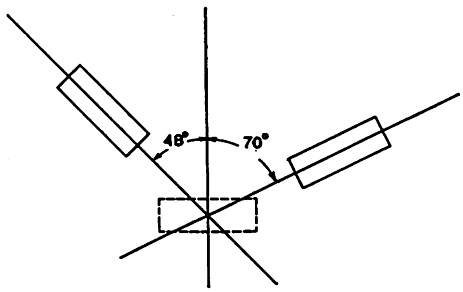
by a battery B and coil L. Associated with the latter are a coil L_1 through which the filament current flows, and a coil L_2 supplied from the high-tension battery. The number of turns and the direction of winding of the coils L, L_1, L_2 are so selected that variations in negative resistance due to any fluctuation in voltage of the several supply batteries mutually cancel one another in their effect upon the electron stream. The generated output is thus determined solely by the tuning of the circuit C.

Patent issued to the C. Lorenz Co., Ltd.

QUARTZ OSCILLATORS.

(*Convention date* (*Germany*), *19th July*, 1927. *No.* 294174.)

As a result of exhaustive research the inventors have ascertained that specially favourable effects can be secured from a crystal cut so that the direction of mechanical oscillation is at an angle either of 70 deg. or 48 deg. to the optical axis. Both these planes have other unique characteristics. For instance the velocity of propagation of sound in the 70 deg. plane is 5,400 metres, whilst in the 48 deg. plane it is 7,700 metres per second. Again in both cases the crystal structure is particularly



regular. Piezo crystals so cut show optimum oscillation properties, and are very sensitive to excitation at their natural frequencies.

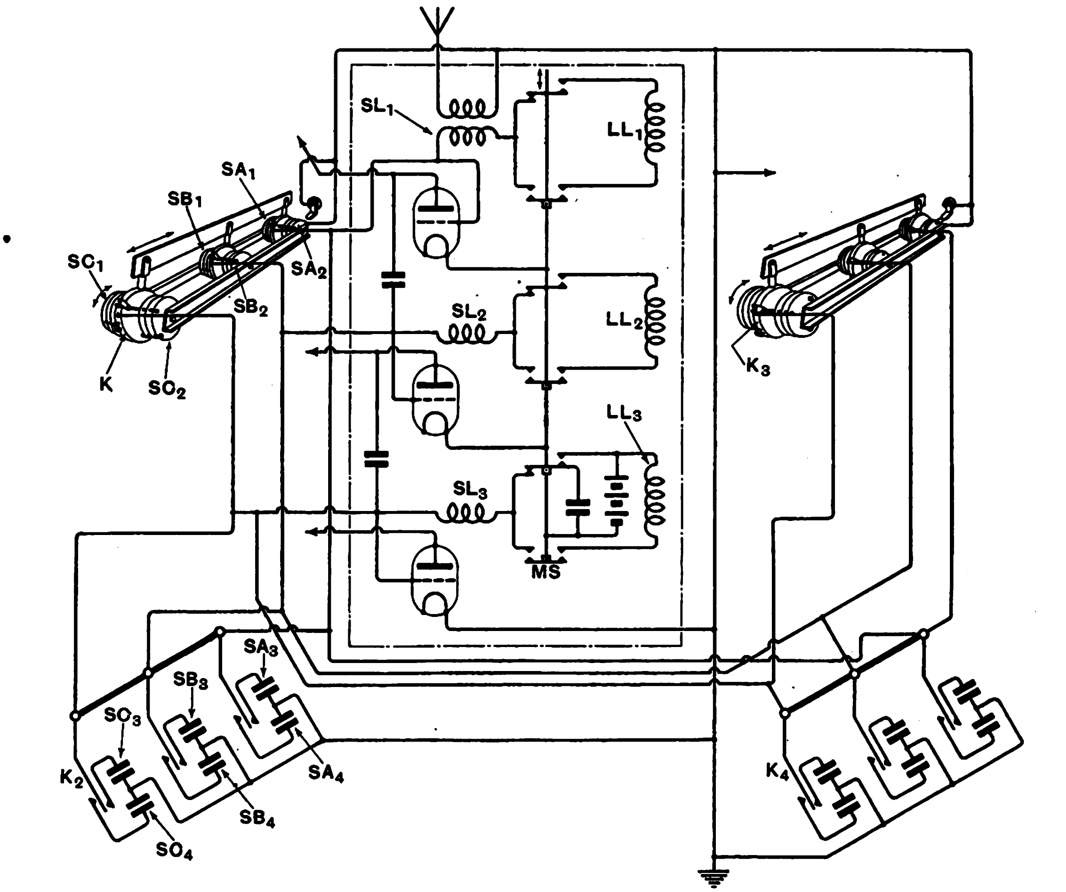
Patent issued to the Telefunken Co., Ltd.

SWITCH-CONTROLLED RECEIVERS.

(*Application date, 23rd September, 1927. No. 295849.*)

The input and tuned intervalve-circuits of a multi-stage high-frequency broadcast receiver are so arranged that selective reception from any one of at least eight different programmes can be secured by the simple operation of tumbler switches. The available stations are so distributed that four are brought in on the short-wave position of a main change-over switch *MS*, and the other four on the long-wave position. In the latter position the loading coils LL_1, LL_2, etc., are inserted in series with the short-wave inductances SL_1, SL_2, etc.

Banks of semi-fixed condensers SA_1, SA_2 . . . SC_4 are so introduced in conjunction with the inductances SL_1, SL_2, SL_3 that, according to the setting of the three-position tumbler switches *K*, K_1, the whole of the inter-valve circuits are simultaneously set to receive one or other of four different short-wave broadcasting stations. The suffixes *A*, *B*, *C* correspond to the different valve stages and the suffixes 1, 2, 3, 4 to different wavelength transmissions, whilst *S*, *L* represent the short and long wave components respectively. A similar arrangement of condensers and switches K_3, K_4 on the right-hand side of the figure enables any one of four different long-wave programmes to be selected.



Patent issued to the British Radio Corporation.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. FEBRUARY, 1929. No. 65.

Editorial.

Transmitting Aerials.

IN no branch of radio-telegraphy or telephony is there greater uncertainty, greater diversity of views or greater possibilities of development along new lines than in the design of transmitting aerials to meet the many new requirements which are arising in various branches of the subject. Since the advent of short-wave telegraphy various methods have been devised for concentrating the radiated energy predominantly into one direction. These methods were at first concerned primarily with the distribution of energy in the horizontal plane, and its concentration towards one point of the compass by means of parabolic reflectors or arrays of vertical aerials, but the further question of the concentration of the beam along a path at a given inclination to the horizontal quickly forced itself upon the attention of those interested in long-distance transmission. If the energy arriving at a distant receiving station is a part of that which was radiated from the transmitting aerial in a certain upward direction, it is obviously desirable to concentrate as much of the radiation as possible in that direction.

A great amount of experimental work on this subject has been carried out in Germany by Dr. Meissner, of the Telefunken Company, using a horizontal Hertzian antenna with a parabolic reflector which could be rocked about a horizontal axis. This reflector consisted of a wooden framework carrying 9 horizontal wires 31 feet long; such an arrangement was found to act as efficiently as a copper sheet reflector. The aperture of the reflector was about 60 feet; standing in the field, the structure looked very much like the skeleton of a grandstand and considerable ingenuity was required to rock it about a horizontal axis through an angle of almost 60 degrees. The receiving station was situated at Buenos Aires.

Experimental Observations.

At first sight one might think it strange that a horizontal aerial was chosen for these large-scale experiments, since the plane of polarisation of the waves is at right angles to that of the waves radiated from a vertical aerial. Seeing, however, that with a vertical transmitting aerial the wave after refraction in the upper atmosphere may arrive at the receiver with its plane of polarisation rotated through a large angle, it is probable that the initial polarisation is of little consequence Such waves with the electric field horizontal cannot travel over the earth's surface in the same way as those with the electric field vertical and they are probably rapidly

attenuated in the neighbourhood of the transmitter, but the tests showed excellent reception in South America. In the early experiments the wavelength was 11 metres and the reflector could be made to direct the beam upwards at any angle between 35 and 90 degrees from the horizontal. The results were erratic; on some days the received signals were much stronger than those from a vertical aerial of ten times the power, whereas on some days they were inaudible. Generally speaking, however, the signals were strong when the transmitted ray had an inclination of 35 to 40 degrees, which was as near the horizontal as was possible with the reflector then in use; as the angle was increased to 60 degrees the signals became much weaker, but on further increasing the angle they became stronger, and for inclinations between 80 and 90 degrees were of about the same strength as for 35 degrees. That strong signals should be received in Buenos Aires when the transmitted ray at Nauen was directed vertically upwards is certainly very surprising. Subsequent arrangements to enable the ray to be directed at smaller inclinations than 35 degrees showed no definite variation in the signal strength from that observed at 35 degrees. The reflector was then enlarged so that the tests could be repeated at the commercial wavelengths of 15 to 20 metres. The results of these tests have recently been published and they show a surprisingly large increase in signal strength as the inclination is reduced from 40 to 0 degrees, the received signals being 5 times as strong when the beam is directed horizontally along the ground as for an angle of 40 degrees and twice as strong as for an angle of 10 degrees. This agrees with the practice of the Marconi Company in making each vertical member of the beam aerial several half wavelengths long, the separate half wavelengths being connected by non-radiating half-wave phasing coils, so that the current in the whole vertical member is simultaneously in the same direction. In a horizontal direction, the effects of all the elements of wire are additive, whereas in other directions they arrive out of phase and tend to cancel out. Hence, for short-wave work there appears to be general agreement that to get the best long-distance transmission the ray should be concentrated in a horizontal direction so that it starts off tangentially from the earth.

At the last meeting of the Wireless Section of the Institution of Electrical Engineers, a paper was read by Messrs. P. P. and T. L. Eckersley and H. L. Kirke on the "Design of Transmitting Aerials for Broadcasting Stations." They favour exactly the same procedure, their conclusions being, "(1) The design of aerials for broadcasting should aim at using the energy to produce the strongest possible horizontal radiation while diminishing upward radiation. (2) To produce this desirable end, high aerials are a *sine qua non.*" It is very interesting to note, however, that their reason for advocating this policy is that they maintain that such a radiation will not be transmitted to a great distance, but will be confined to a limited area around the transmitter, and consequently will not cause interference with distant transmitters. In contemplating this apparent paradox it must be remembered that the wavelength in the first case is about 20 metres, and in the second from 200 to 600 metres, and that although they are both electromagnetic waves, they behave very differently.

Congestion of Wavelengths.

The idea on which this new suggestion is based is that the difficulties in finding accommodation for all the broadcasting stations in the wavebands available are largely caused by interference from very distant stations, due to the energy radiated above the horizontal, which after refraction in the upper atmosphere produces strong signals at distances far beyond what could possibly be regarded as the service area of the station in question. Undoubtedly the problem which we discussed in our January number would be greatly simplified if the radiation from every station could be attenuated to a negligible amount at a certain radius so that it could be guaranteed to cause no interference beyond that radius. At present this is far from being the case, and therein lies what to many people is the chief attraction of broadcasting, for there is no doubt that to many listeners the reception of distant stations, even at some sacrifice of quality, is more attractive than the perfect reception of stations nearer home. We do not think that such people

An Apparatus for the Projection of Frequency-Output Characteristics.

By C. G. Garton and G. S. Lucas.

(Engineering Laboratory, B.T.H. Co., Ltd., Rugby.)

IN the course of any serious work on the design either of amplifiers, intervalve transformers, or loud speakers, it becomes necessary to obtain curves connecting the frequency of the input power and the amplitude of the resultant output, more briefly called the "frequency-output" characteristic. These curves have for some years been familiar to those interested in the subject in the case of intervalve transformers, but it is only comparatively recently that careful investigation has been made into the frequency characteristics of complete amplifiers and loud speakers.

Although the importance of an accurate knowledge of the frequency characteristic has for some time been realised, the methods available for obtaining such curves have been extremely tedious, and have prevented the development which the importance of the subject deserves.

The obvious method of obtaining the required information is to provide a source of power of adjustable frequency, and to take a series of simultaneous readings on input and output meters. Anyone familiar with work of this type will realise the time required and the difficulties involved in repeating results owing to gradual changes in the apparatus with time. In the case of loud-speaker characteristics, also, the curve is of such an irregular nature that a very great number of readings is necessary before an accurate result can be obtained.

Efforts have been made by various experimenters* to evolve bridge methods of measurement, in which the ratio of input to output is determined by obtaining zero deflection or zero sound on a galvo. or telephone respectively. While these methods eliminate the tediousness of taking numerous meter readings, the time required is still inconveniently long, and considerable care is necessary in order to obtain satisfactory results. Moreover, bridge circuits take account of phase relationship between input and output, which renders the method inapplicable to loud-speaker problems, since the phase of the emitted sound arriving at the measuring microphone varies with the relation between the wavelength and the distance separating the loud speaker and microphone. The complication introduced by this more than counterbalances any advantages of the method.

The authors, being continually concerned with the characteristics of audio-frequency apparatus, were led to devise an equipment which should quickly and automatically trace the frequency characteristic of any piece of apparatus appropriately connected with it, the labour involved being thus reduced to the mere operation of control knobs, and the time to a negligible amount.

With such a device it is feasible to take a large number of curves in quick succession, without undue labour or fatigue, making it possible for the experimenter quickly to see the results of any changes made in the apparatus under investigation. Moreover, the experimenter is left free to concentrate on the work in hand, without being distracted by the routine task of taking numerous readings.

It should be acknowledged at this point that the basic idea of such a method is not novel, a somewhat similar scheme having been described by B. S. Cohen and colleagues†, but their apparatus, as published,

* "The Performance of L.F. Transformers," D. W. Dye, B.Sc., *E.W. & W.E.*, September, 1924, Vol. I, p. 691. "The Performance of Amplifiers," H. A. Thomas, M.Sc., *J.I.E.E.*, February, 1926, Vol. 64, p. 253. Discussion, *ibid.*, p. 274. "L.F. Intervalve Transformers," P. W. Willans, M.A., *J.I.E.E.*, October, 1926, Vol. 64, p. 1065.

† "Frequency Characteristics of Telephone Systems and Audio-frequency Apparatus," B. S. Cohen, A. J. Aldridge and W. West, *J.I.E.E.*, October, 1926, Vol. 64, p. 1023.

is applicable only to the taking of photographic records, whereas the authors, by incorporating a second deflecting mirror, are able to obtain characteristics projected upon a stationary screen, a form more suited to laboratory work where rapid and non-permanent indications are desired. Moreover, Cohen's method involved the rectification of the output from the apparatus under test, in order to secure the operation of a moving coil galvanometer, while the authors, by developing a novel and very sensitive form of hot wire galvanometer, are able to dispense with rectification and its attendant difficulties.

The object of this paper is to give a description of the construction, operation and scope of the projecting apparatus. The detailed construction of each component will be dealt with at a later stage, but the following paragraphs will give a general outline of the principles involved and the necessary apparatus.

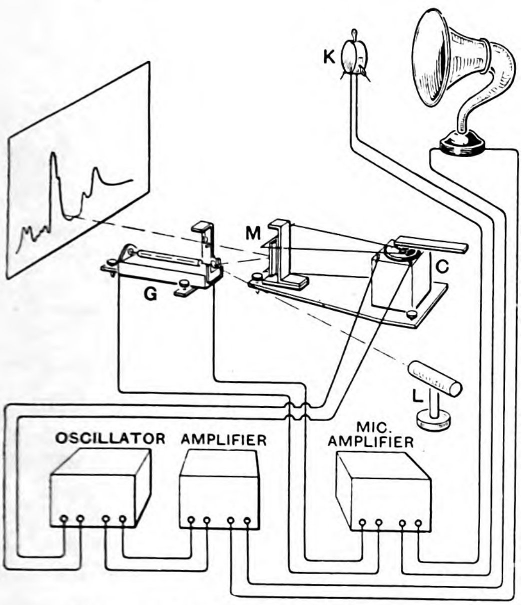


Fig. 1.—*Arrangement of Apparatus.*

The first essential in any method of tracing frequency characteristics is a source of power of which the frequency can be continuously varied over the entire audio range, without variation of the voltage or current supplied. Such a device is termed a "constant voltage generator." Secondly, in order to project a curve in rectangular co-ordinates, two deflections at right angles are required; one providing a horizontal scale of frequency; the second, in a vertical direction, representing output. The second deflection is readily obtained by the motion of a galvanometer mirror actuated by the output of the apparatus under test. The

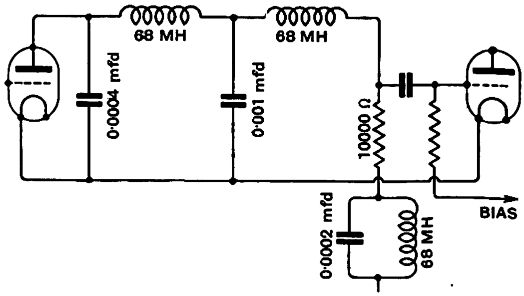


Fig. 2.—*Filter Circuit.*

frequency deflection may be obtained by turning the galvanometer bodily about an axis normal to the axis of deflection of its mirror, in synchronism with the frequency control of the generator; or more conveniently by a mirror mechanically coupled to the frequency control, on which the beam of light falls in its passage from the galvo. mirror to the screen. The latter alternative has been chosen by the authors as simplifying the design of the galvo.

Fig. 1 gives a schematic view of the apparatus as arranged for obtaining the characteristic of a loud speaker. Power from the constant voltage generator is supplied to the loud speaker, the sound energy emitted being picked up by a microphone *K* and passed on to an amplifier. The amplified energy, proportional to the output of the loud speaker, operates the galvo. *G* (shown in detail in Fig. 4), thus deflecting the beam of light along a vertical axis. A condenser *C*, forming the frequency control of the generator, is coupled to the second mirror *M*, as shown more completely in Fig. 3. Variation of the frequency, by rotation of *C*, thus causes a corresponding deflection of the light beam along the horizontal frequency axis. The simultaneous combination of the two deflections obviously traces the "frequency-output" characteristic of the loud speaker. Particulars of the circuit modifications necessary for obtaining

curves on transformers and amplifiers will be given after the detailed description of the apparatus.

The constant voltage generator used is substantially that described by H. L. Kirke* in *E.W. & W.E.*, but with certain small modifications found necessary in the course of experiment. For the benefit of those not having access to Kirke's paper, it may be briefly explained that the generator consists of two radio-frequency oscillator circuits, tuned to about 10^5 cycles, of which one is variable over the range $.9 \times 10^5$ to 1.0×10^5 cycles. The difference frequency, variable from 0 to 10^4 cycles, is picked up in a "mixing" circuit, detected, and amplified. A variable condenser in the tuned circuit of one oscillator forms a convenient means of varying the output frequency.

The main modification which the authors found necessary was in the method of filtering out unwanted radio-frequency components from the audio-frequency output. With the published arrangement of filter circuits it was found impossible, in the authors' generator, simultaneously to obtain a uniform "frequency-output" characteristic and an adequate freedom from radio-frequency interference. The cause could not be discovered, but the difficulty was solved by the use of a different filter circuit, shown in Fig. 2, interposed between the

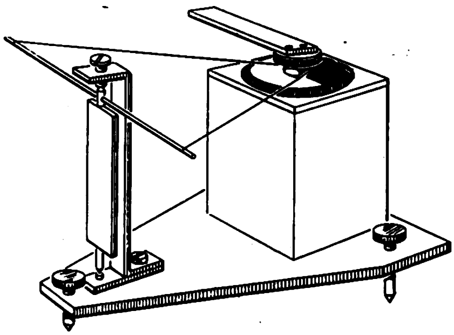


Fig. 3.—*Rotating Mirror.*

detector valve and the first amplifier. The other filters were discarded. Other modifications were the provision of two large-power valves in the final stage, giving an output of 2.5 watts, and the substitution of a potentiometer resistance in the output circuit in place of an output transformer. The characteristics of the latter device are likely to vary with the type of load which is being supplied; a resistance is more stable in this respect. The final stage is "choke-capacity" coupled to the output circuit, and a useful addition, when working on loud-speaker characteristics, is a variable high resistance across this capacity; so that a D.C. component may be superposed on the alternating output of the generator. The variation in output is within ± 2 per cent. between 100 and 10,000 cycles, and within 5 per cent. at 50 cycles.

* "The Design of a Heterodyne Type Low Frequency Oscillator," H. L. Kirke, *E.W. & W.E.*, February, 1927, Vol. 4, p. 67.

As previously explained, frequency control is obtained by a condenser in the tuned circuit of one oscillator, and use is made of the rotation of this condenser to operate the deflecting mirror which provides the frequency axis. As shown in Fig. 3, the mechanical coupling between mirror and condenser is of the simplest possible form. A thread passing round the spindle of the condenser is secured at both ends to opposite arms of a bar passing through the mirror spindle. The thread may be tightened by winding the surplus upon the bar, while different "gear ratios" are obtained by spreading the ends nearer or farther apart along its length. The calibration of the frequency scale will not in general be uniform, but will depend upon the shape of the condenser plates and upon the mechanical characteristics of the coupling. The authors have found convenient a scale which is "spread out" at the lower end up to about 1,000 cycles, and is thereafter approximately linear.

The flexible lead from the oscillator circuit to the condenser and the condenser itself should preferably be shielded to avoid erratic changes of frequency due to movements of the operator.

The next essential component to be described is the galvanometer, which records the output of the apparatus under test. The requirements are:—

(1) That it should be sensitive, so as to demand as little power as possible from its associated amplifier.

(2) Its indications should be independent of phase and frequency.

(3) It should be capable of being arranged to deflect about a horizontal axis, so that the "output" scale is projected vertically.

Requirement (1) rules out the use of soft iron instruments; dynamometer types do not comply with (1) if both windings be supplied from the same source, nor with (2) if the field be separately excited, while requirement (3) prevents the use of any type involving the usual galvanometer suspension.

We are left with three possibilities; rectification of the output, and the use of a pivoted moving coil milliammeter; a vacuo-thermo-junction and a pivoted micro-

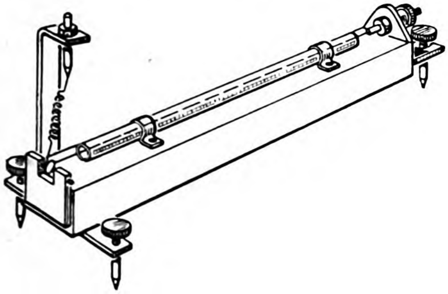


Fig. 4.—*Galvanometer.*

ammeter; or some form of hot wire instrument. The first expedient, as noted above, has been successfully used by B. S. Cohen, operating a suspended type of galvanometer, but the problem of obtaining distortionless rectification of sufficient power to operate a moderately robust pivoted instrument is one to be avoided if other methods are available. The second suggestion, which obtains rectification by a thermo-junction, would probably be quite successful, but the microammeter required would be a somewhat delicate and costly instrument.

The authors finally decided to eliminate rectification altogether, and to concentrate upon the design of a suitable hot wire instrument, and an unexpectedly simple construction proved to have all the required characteristics. The essential features of the design are shown in Fig. 4. A fine filament of tungsten, forming the hot wire, is secured at one end to the wooden base by a tensioning screw, and at the other end passes through 90 deg. around a small steel spindle free to rotate in jewelled pivots. The free end of the wire is then secured to a helical spring, which holds it in tension. It will be realised that any expansion of the wire, due to current passed through it, will result in a corresponding rotation of the small spindle, provided that slip does not occur between it and the wire. A galvanometer mirror, secured to the spindle with shellac, serves to record the amount of rotation upon the screen. Since the angular motion obtained, for a given expansion of the wire, is inversely proportional to the diameter of the spindle, the sensitivity may be increased indefinitely by decreasing the diameter, subject to mechanical limitations.

Some dimensions and practical details of the authors' instrument will be useful to anyone contemplating the construction of a similar device. The wire used is of tungsten 16in. long and 0.0006in. (six ten-thousandths) in diameter. The spindle is of hardened steel, ground to pivot points at the ends, ⅜in. in length, and 0.025in. in diameter The mirror attached to it is the usual galvanometer type, of ⅜in. diameter and 2 metres focal length. The tension upon the wire does not appear to be important, so long as it is sufficient to keep the wire straight, and tightly stretched around the spindle. The base, which carries the fixed supports, is of wood and is provided with three levelling screws. It is essential that the wire be protected from draughts, and it is therefore surrounded by a metal tube, ½in. diameter and 15in. long, slotted longitudinally so that it may be placed in position over the wire, and secured to the base.

The technique of handling tungsten wire of such small diameter is somewhat difficult, but is soon acquired. Work should be carried on in a strong light over white paper, using instrument tweezers for manipulation. The ends of the wire are best secured by the use of a short length of soft nickel or copper wire about .04in. in diameter. One end of this is hammered flat and bent over upon itself through 180 deg., so forming a flat hook. The end of the tungsten wire is drawn into this, and the hook strongly compressed upon it with pliers. A few trials will show the degree of compression needed to grip the tungsten firmly without breaking it. When equipped with these ends the wire may be secured in any desired manner to the tensioning screw and spring. After a little experience a new wire can be mounted in less than half an hour. When the wire is in position and under tension it is desirable to pass through it momentarily a current as great as can be used without destructive

effect (about 100 milliamps in the case of .0006in. tungsten). This has the double effect of annealing any kinks in the wire, and of removing traces of grease, etc., which cause the wire to cling to the spindle instead of rolling freely. To prevent slipping between wire and spindle a minute spot of shellac should be applied after the wire is in position. The spot must be so small that it does not reach the points where the wire is to roll on and off the spindle, and it is best applied with a penknife blade, covered with a film of nearly dry shellac varnish, and held at 45 deg. to the direction of the wire.

The calibration obtained is given in Fig. 5.

In the authors' instrument no attempt has been made to provide compensation for changes in ambient temperature, and the zero is consequently somewhat unstable, but it is a simple matter to re-level the instrument before taking a curve. Also, no attempt has been made to obtain maximum sensitivity, nor are the dimensions quoted above in any way critical, the instrument being the first model constructed from spare material readily available in the laboratory.

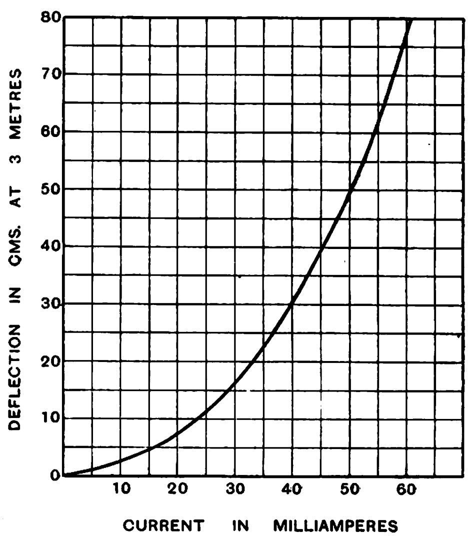


Fig. 5.—*Calibration Curve of Galvanometer.*

There is no doubt that by using finer wire and a smaller spindle, or by employing one of the mechanical multiplying devices common on hot wire instruments, the sensitivity could be increased, but the authors have preferred to retain the simplicity and robustness of the first model, since ample power was available to operate it.

The optical system finally adopted for projecting the spot of light is extremely simple. A small (10 amp.) carbon arc lamp is provided with an opaque diaphragm pierced with a circular hole ¼in. in diameter. The divergent cone of light emerging falls on the galvanometer mirror, and is reflected thence to the larger mirror of the frequency control device, from which it is reflected to the screen. The galvanometer mirror having a focal length of 2 metres, if the arc be placed at about that distance from the mirror an approximately parallel beam will be reflected therefrom. Although this does not form a true optical image upon the screen the spot obtained is sufficiently definite, and the method has the advantage of requiring no lenses and no accurate focussing. A suitable arrangement of the various components is shown in Fig. 1.

If a more intense spot of light is required, a convex lens, about 0.25 metres focal length, may be placed directly in front of the arc lamp diaphragm, which has the effect of directing more light upon the mirror. The spot is made somewhat larger, but much brighter.

In obtaining loud-speaker characteristics a microphone and amplifier are needed to operate the galvanometer. These will now be described. The choice of microphone is practically limited to three types: a good type of carbon instrument, such as the Reisz pattern; the magnetophone, which depends on the motion of a coil in an annular magnetic field; and the electrostatic type in which the motion of a stretched membrane is used to give capacity variations corresponding to the sound pressure.

From considerations of sensitivity the carbon microphone is much to be preferred, being between 10^2 and 10^3 times more sensitive than the other types; but it is inherently unstable in its characteristic, depending as it does on the chance variations of contact between carbon granules. With a well-designed instrument, quite good results are obtainable, but the authors feel that it is advisable for regular work in the laboratory to adopt a more stable type. For lecture and demonstration purposes, where the great insensitivity of other types would demand inconvenient values of amplifi-

cation, the carbon pattern is undoubtedly preferable. As between the magnetophone and the condenser microphone, the latter has the advantage of small bulk, and does not require an auxiliary magnetic field; the authors have therefore adopted the latter instrument. With any microphone it is, of course, essential to have a calibration of the instrument (generated volts against frequency) obtained by some absolute method such as the Rayleigh disc.*

necessary that the impedance of the microphone shall be small compared with the value of *R*. The capacity of the microphone used by the authors is only 200 cms., corresponding to an impedance of 14.3 megohms at 50 cycles, and it will be obvious that a value for "R" large compared with 14 megohms is not practicable. Accordingly, a fixed condenser is used in parallel with the microphone, bringing the total capacity to 500 cms., which when used with a 10

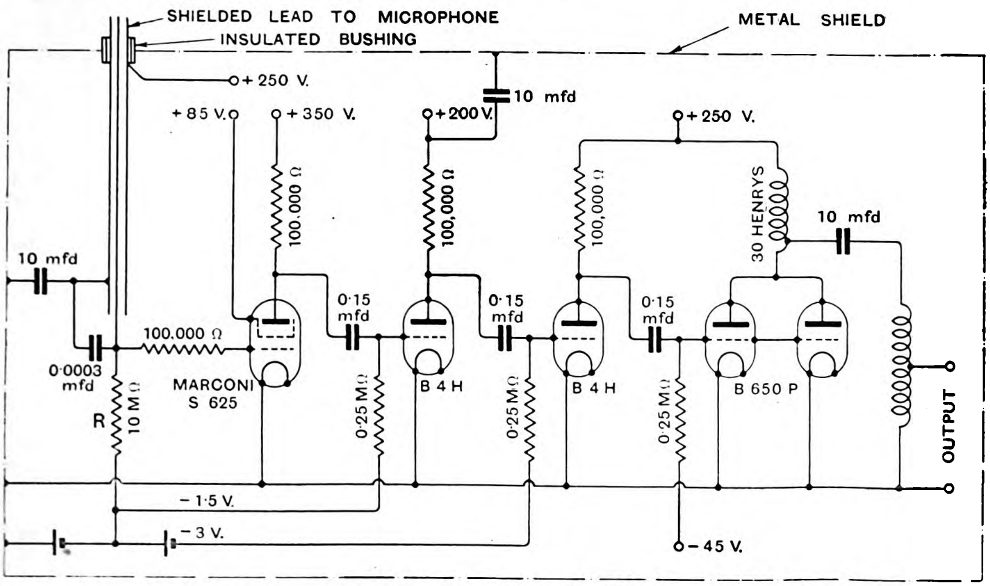


Fig. 6.—*Microphone Amplifier.*

Although it is not at present possible to design a microphone having a linear characteristic over the entire frequency range, such a characteristic can be achieved for the amplifier, and is highly desirable in order to minimise the necessity for correcting the curves obtained. Consequently, a fairly comprehensive description will be given of this part of the apparatus. The connection diagram, with appropriate values, is shown in Fig. 6, but there are a number of points in the design which require explanation.

The coupling of the microphone to the first grid is obtained through the resistance "R," and in order to obtain a satisfactory amplification of the lower frequencies it is megohm value for "R" gives 87 per cent amplification at 50 cycles. It is important that the insulation resistance of the microphone and the parallel condenser should have the highest possible value, since any leakage which occurs will flow through the the resistance "R" and affect the grid bias voltage. Since 200 volts are used on the microphone, a leakage resistance of 1,500 megohms will result in +1.5 volts being applied to the grid circuit, and lower values will give positive grid bias, causing loss of amplification, more particularly at low frequencies, where the microphone impedance is large.

The amplifier is a standard resistance capacity coupled type, with the exception of the first stage, where a screen grid tetrode valve is employed. Although the use of this

* "The Technique of Testing Microphones and Receivers," B. S. Cohen, M.I.E.E., *J.I.E.E.*, February, 1928, Vol 66, p. 185.

type of valve for audio-frequency amplification is not yet common, very satisfactory results are obtainable where a high voltage amplification is desired, and when adequate plate voltage is available. With the values given in Fig. 6, a "step-up" of about 50 to 1 on the first stage is obtained.

The design of the final stage is a matter of considerable importance, since a large amount of power (2.5 watts) is to be handled, with uniform amplification from 50 to 10^4 cycles. "Choke-capacity-transformer" coupling has been adopted, a transformer being necessary owing to the low resistance of the galvanometer, and the capacity coupling serving to keep the superposed D.C. from magnetising the transformer core, thus considerably facilitating the design of the latter. It is difficult, and probably impossible, to design an output transformer to carry a large superposed D.C. current and yet have a good characteristic at both ends of the frequency scale. The transformer used consists of a ring core 2in. in depth, and with stampings $4\frac{5}{8}$in. and $2\frac{1}{4}$in. in external and internal diameters respectively. This is wound with 2,500 turns of .0148in. silk-covered wire, of which 700 turns are tapped off at one end to form the secondary. The secondary section is interleaved between two primary sections, to reduce the leakage reactance.

In general, the characteristic of the amplifier will not, without some adjustment, prove to be level. A tendency to rise at the higher frequencies may be overcome by a small condenser (about 1 to 10 cms.), between the plate and grid of either the second or third valves. An opposite tendency may be neutralised by a similar value of capacity between the plate of the third valve and the grid of the second. These expedients operate by introducing negative and positive reactions respectively, which increase with the frequency. The second method must not be carried to excess, or the amplifier will oscillate.

The method adopted to check the characteristic of this amplifier is shown diagrammatically in Fig. 7. A small voltage is tapped off from the output potentiometer of the constant voltage oscillator, and is injected into the microphone circuit. The condenser "*C*" in Fig. 6 is replaced by one of .0003 mfd., as the 10 μF normally used would short-circuit the injected voltage, also a resistance of 10,000 ohms is inserted in the battery lead for the same reason. By rotating the frequency control the characteristic of the amplifier corresponding to constant voltage from the microphone will

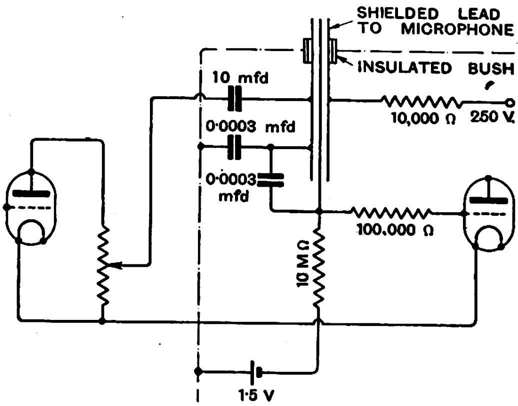


Fig. 7.—*Microphone Calibration Circuit.*

be obtained. The total drop at 50 cycles, including the generator drop, is about 20 per cent., and at 100 cycles 5 per cent., the remainder of the curve is flat within $\pm$ 2 per cent.

A few precautions are necessary in the design of so sensitive an amplifier to prevent radio-frequency transients from being amplified, otherwise any slight disturbance of the circuit, due to switching for instance, results in sudden and destructive deflections of the galvanometer. The resistance of 0.1 megohm in series with the first grid is one such precaution, also the 10 μF condenser directly connected to the shielding of the condenser cable, and the multiple earthing of the filament circuits by the shortest possible paths as shown. Of course, the whole must be enclosed in a metal box, and this is preferably enclosed again in a heavily felt-lined box to avoid noise from the loud speaker under test reaching the valves and giving spurious microphonic amplification.

In obtaining the characteristics of loud speakers it is essential to specify the type of enclosure in which the loud speaker and microphone are placed, since the sound arriving at the latter is not only that proceeding directly from the former, but is the sum of all the echoes returning from adjacent

walls and objects. The ideal would be a room so heavily draped with sound absorbent materials that no echoes could occur, but this cannot be realised in practice, as all available substances reflect more or less of the sound incident upon them. The echoes in any ordinary room are of sufficient magnitude to mask the true nature of any characteristic obtained in it, and it is therefore essential that such tests be carried out in a special room rendered as nearly echoless as possible. That used by the authors is built of wood, 12 ft. by 9 ft. in plan and 9 ft. high. The walls, ceiling and floor are loosely draped with two layers of soft felt, each ½ in. in thickness, and one layer of cotton wool. Although standing waves are not entirely eliminated, they are sufficiently reduced that the general shape of the curves obtained is correct, as determined by numerous check tests taken under various conditions, though significance cannot be attached to every peak and valley. Many workers in acoustics advocate swinging the microphone through an arc while taking readings, in order to average out the effect of standing waves. This method cannot readily be applied to the authors' apparatus, as the light damping of the galvanometer enables it to follow the variations in intensity as the microphone swings, giving a band instead of a line curve. However, by heavily damping the galvanometer with an oil-immersed vane, this can be prevented, and work along these lines is proceeding.

We have dealt, so far, mainly with the circuits necessary for the testing of loud speakers, but the apparatus is equally applicable to the obtaining of characteristics of amplifiers and transformers.

In the case of an amplifier, the input circuit is supplied from the constant output oscillator with a constant value either of current or voltage, according to the circumstances under which the amplifier will normally be used. If the final stage of the amplifier is sufficiently large to operate the hot wire galvanometer, it may be coupled to that instrument through a suitable transformer; otherwise, it is loaded on an appropriate resistance, the voltage across which is used to operate the final stage of the microphone amplifier described above, to which the galvanometer is connected.

In the case of an intervalve transformer a two-stage amplifier should be set up, using the transformer in question for coupling purposes. The first valve must, of course, be the type with which it is intended normally to operate the transformer, and its grid is supplied as in the previous arrangement, with constant voltage from the generator. The second valve has also an influence on the results at high frequencies, due to its reaction upon the transformer secondary; therefore it should if possible also be similar to that with which the valve will normally work.

It is important, in all these tests, to keep a direct earth connection through all the various amplifier circuits, or unexpected reactions may occur. It is a good practice to earth every negative filament connection. When working in a laboratory subject to radio-frequency disturbance it is essential to use shielded cable when making connec-

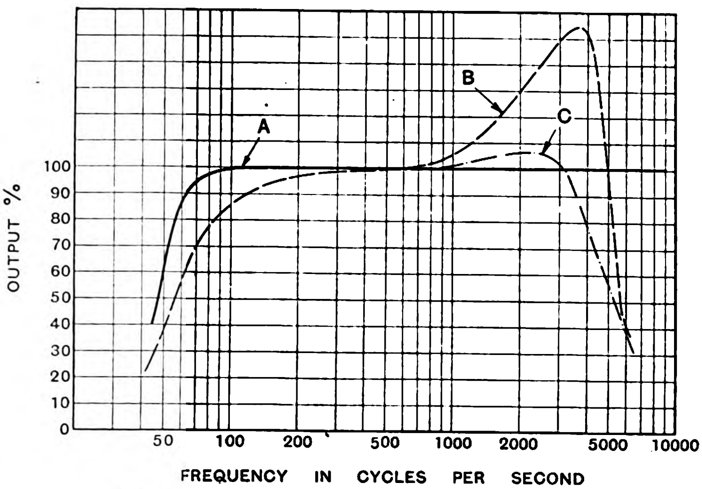


Fig. 8.—*Amplifier Characteristic Curves:*
A—Resistance-capacity-coupled.
B—Transformer-coupled.
C—As "B" Transformer Connections reversed.

tions from the generator to the grid circuits of amplifiers.

In Figs. 8 and 9 are given some typical curves obtained by the use of the apparatus. In Fig. 8 are shown characteristic curves for resistance-coupled and transformer-coupled two-stage amplifiers. Curves "*B*" and "*C*" illustrate well the effect of inter-electrode capacity reaction in producing peaks at the higher frequencies, and how this can vary with the direction of the transformer winding. Fig. 9 is typical of results obtained upon loud speakers. Curve "*A*" is obtained from a well-known make of horn type instrument, curve "*B*" from the best available moving coil type, and "*C*" from an instrument similar to "*B*" but with a diaphragm of unsuitable material.

While the greatest field of use for this apparatus lies probably in facilitating quick observation of the effect of changes made during the course of experimental work, it is also well adapted for lecture purposes, since the curves are obtained in large size on a screen, readily visible to an audience. A desirable addition, for laboratory work, would be a camera attachment to the galvanometer, so that permanent records could be obtained if desired, but no work has yet been done in this direction.

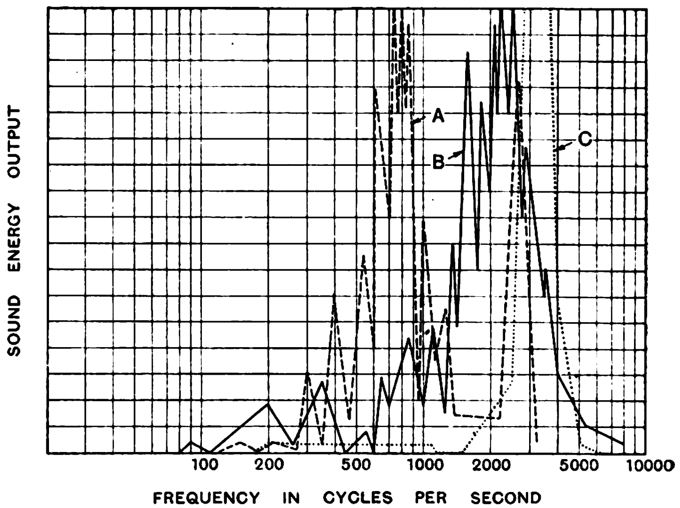


Fig. 9.—*Loud Speaker Curves :*
A—Horn Type Loud Speaker.
B—Good Moving Coil Loud Speaker.
C—Bad Moving Coil Loud Speaker.

In conclusion, the authors wish to express their thanks to the B.T.H. Co., Ltd., for ths use of the resources of their Engineering Laboratory, without which the experimental work of this paper could not have been accomplished.

Effect of Anode-Grid Capacity in Anode-Bend Rectifiers.

By E. A. Biedermann, B.Sc., A.M.I.E.E.

Introduction.

THIS subject has been discussed by Mr. W. B. Medlam* in a recent issue of *E.W. & W.E.*, and the conclusion reached that the feed-back due to the anode-grid capacity of the valve leads to considerable distortion. In the writer's opinion, Mr. Medlam's analysis is open to considerable criticism for reasons which are given in the correspondence columns of this issue.

The object of this article is to outline what the writer believes to be the correct theory of the subject, which it will be found leads to results quite opposite to those arrived at by Mr. Medlam.

The case considered by Mr. Medlam is that of an anode-bend detector valve with an input circuit consisting of an inductance L, of resistance r, in parallel with a tuning capacity C, which may be considered to include the grid-filament capacity of the valve.

The anode circuit radio-frequency load is treated in the paper referred to as purely capacitative on the grounds that the impedance, at radio-frequency, of the capacity in the anode circuit is always much less than that of the resistance, or inductance. While this is, no doubt, mostly the case, it may not be so invariably—for example, with *RC* coupling using a comparatively low value of anode resistance—and as it is not obvious what the effect of the resistance may be, the more general case will be considered of an anode circuit consisting of a resistance R_a in parallel with a capacity C_a. In the case of transformer coupling it will certainly be legitimate to regard the anode circuit as being for all practical purposes purely capacitative so far as the radio-frequency is concerned. This case is therefore obtained by making R_a infinite.

For convenience of comparison the same symbols will for the most part be employed as in the article referred to, but $E \sin \omega t$ will in the present article be taken to denote, not the grid-filament potential difference, but the effective E.M.F. acting in the input circuit.

The method of impedance operators will be used instead of the differential equations employed by Mr. Medlam, the former method facilitating the mathematical work.

Input Circuit Relations.

The equivalent circuit of the valve with its associated input and output circuits, as described above, is shown in Fig. 1, where the arrows denote the directions in which

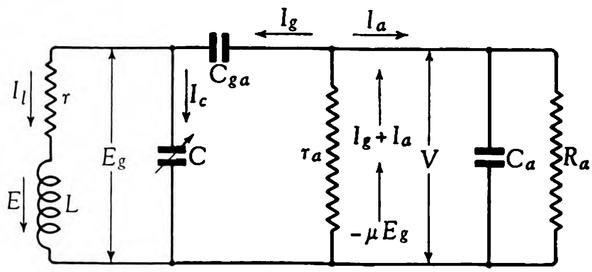


Fig. 1.

the various currents and voltages are regarded as positive for the purpose of forming the circuit equations.

The same symbols will be used for the vectors representing the various quantities as for the maximum values of those quantities, since it is easy to distinguish where the vector quantities are referred to and where the scalar magnitudes.

Referring to the figure, we have the following relations for the input circuit, where E denotes the effective E.M.F. acting in the inductance of the input circuit:

* Effect of Anode-Grid Capacity in Detectors and L.F. Amplifiers, by W. B. Medlam, B.Sc., A.M.I.E.E. (*E.W. & W.E.*, Oct., 1928).

$$E + E_g = (r + j\omega L)I_l \quad \ldots \quad \ldots \quad (1)$$
$$I_c = j\omega C E_g \quad \ldots \quad \ldots \quad \ldots \quad (2)$$
$$I_g = I_l + I = j\omega C_{ga}(V - E_g) \quad \ldots \quad (3)$$

from which

$$I_l = I_g - I_c = j\omega C_{ga}V - j\omega(C + C_{ga})E_g$$

and hence, by (1)

$$E + E_g = (r + j\omega L)\{j\omega C_{ga}V - j\omega(C + C_{ga})E_g\} \quad \ldots \quad (4)$$

We shall now introduce the, at present, undetermined relation

$$V = -(\mu_1 + j\mu_2)E_g \quad \ldots \quad \ldots \quad (5)$$

On substituting this in (4), we obtain

$$E + E_g = (r + j\omega L)\{(\mu_2 - j\mu_1)\omega C_{ga} - j\omega(C + C_{ga})\}E_g$$

so that

$$E_g = \frac{E}{\{(\omega^2 LC_0 - 1 + \mu_2 r\omega C_{ga}) - j(r\omega C_0 - \mu_2\omega^2 LC_{ga})\}} \quad \ldots \quad \ldots \quad (6)$$

where

$$C_0 = \{C + (\mu_1 + 1)C_{ga}\} \quad \ldots \quad \ldots \quad (7)$$

Hence the instantaneous value of E_g is given by

$$e_g = E_g \sin(\omega t + \theta) \quad \ldots \quad \ldots \quad (8)$$

where

$$E_g = \frac{E}{\sqrt{(\omega^2 LC_0 - 1 + \mu_2 r\omega C_{ga})^2 + (r\omega C_0 - \mu_2\omega^2 LC_{ga})^2}} \quad \ldots \quad \ldots \quad (9)$$

and

$$\tan\theta = \frac{(r\omega C_0 - \mu_2\omega^2 LC_{ga})}{(\omega^2 LC_0 - 1 + \mu_2 r\omega C_{ga})} \quad \ldots \quad (10)$$

Output Circuit Relations.

Referring again to Fig. 1, the anode circuit relations are

$$V = -\mu E_g - r_a(I_g + I_a) \quad \ldots \quad (11)$$
$$I_g = j\omega C_{ga}(V - E_g) \quad \ldots \quad \ldots \quad (12)$$
$$I_a = \left(\frac{1}{R_a} + j\omega C_a\right)V \quad \ldots \quad \ldots \quad (13)$$

from which

$$V = -\mu E_g - r_a\left\{j\omega C_{ga}(V - E_g) + \left(\frac{1}{R_a} + j\omega C_a\right)V\right\}$$

so that

$$V = \frac{-(\mu - jr_a\omega C_{ga})E_g}{\left\{\left(1 + \frac{r_a}{R_a}\right) + jr_a\omega(C_a + C_{ga})\right\}}$$

$$= -\frac{\left[\left\{\mu\left(1+\frac{r_a}{R_a}\right) - r_a^2\omega^2(C_a + C_{ga})C_{ga}\right\} - jr_a\omega\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}\right]E_g}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}}$$

Comparing this with (5), we obtain

$$\mu_1 = \frac{\left\{\mu\left(1 + \frac{r_a}{R_a}\right) - r_a^2\omega^2(C_a + C_{ga})C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}} \quad (14)$$

$$\mu_2 = \frac{-r_a\omega\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}} \quad (15)$$

Tuning Condition and Corresponding Value of E_g.

It will be seen that both μ_1 and μ_2 are independent of C, so that $\frac{dC_0}{dC} = 1$, by (7), and the condition for E_g to be a maximum for the carrier wave frequency, for which we may put $\omega = \omega_c$, is, from (9), found to be

$$C_0 = \frac{L}{(r^2 + \omega_c^2 L^2)} \quad \ldots \quad (16)$$

Substituting this value of C_0 in (9), we find

$$E_g = \frac{E}{\sqrt{\left\{\frac{\omega^2 L^2}{(r^2 + \omega_c^2 L^2)} - 1 + \mu_2 r\omega C_{ga}\right\}^2 + \left\{\frac{r\omega L}{(r^2 + \omega_c^2 L^2)} - \mu_2\omega^2 LC_{ga}\right\}^2}},$$

which reduces to

$$E_g = \frac{\sqrt{r^2 + \omega^2 L^2}\,E}{\sqrt{\{r - \mu_2(r^2 + \omega^2 L^2)\omega C_{ga}\}^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2 L^6}{(r^2 + \omega_c^2 L^2)^2}}},$$

and for the corresponding value of $\tan\theta$ we find from (10)

$$\tan\theta = \frac{\{r - \mu_2(r^2 + \omega_c^2L^2)\omega C_{ga}\}\omega L}{-\left\{(r - \mu_2(r^2 + \omega_c^2L^2)\omega C_{ga}) - \frac{(\omega^2 - \omega_c^2)L^2}{r}\right\}r}.$$

Since $\frac{r^2}{\omega^2L^2}$ is always very small compared with unity, we can neglect r^2 compared with ω^2L^2 and $\omega_c^2L^2$, so that the above expressions reduce to

$$E_g = \frac{\omega LE}{r\sqrt{\left(1 - \frac{\mu_2\omega^3L^2C_{ga}}{r}\right)^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2L^2}{\omega_c^4r^2}}} \quad \ldots \quad (17)$$

and $\tan\theta =$

$$\frac{(r - \mu_2\omega\omega_c^2L^2C_{ga})\omega L}{-\left\{(r - \mu_2\omega\omega_c^2L^2C_{ga}) - \frac{(\omega^2 - \omega_c^2)L^2}{r}\right\}r} \quad (18)$$

Evaluation of E_g in Terms of $\frac{m}{\omega_c}$.

Putting $\mu_2 = -\omega\phi(\omega)$ .. .. (19)

where, from (15),

$$\phi(\omega) = \frac{r_a\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega^2(C_a + C_{ga})^2\right\}} \quad (20)$$

we have for any side band frequency $\omega = (\omega_c + m)$ (where m may have both positive and negative values).

$$\begin{aligned}\phi(\omega) &= \phi(\omega_c + m) = \phi(\omega_c) + m\phi'(\omega_c) + \tfrac{1}{2}m^2\phi''(\omega_c) + \text{etc.}\\ &= \phi(\omega_c)\left\{1 + \frac{\omega_c\phi'(\omega_c)}{\phi(\omega_c)}\frac{m}{\omega_c} + \frac{\omega_c^2\phi''(\omega_c)}{2\phi(\omega_c)}\frac{m^2}{\omega_c^2} + \text{etc.}\right\}\\ &= \phi(\omega_c)\left\{1 - 2a\frac{m}{\omega_c} - a(1-4a)\frac{m^2}{\omega_c^2}\right\} \quad (21)\end{aligned}$$

on neglecting higher powers of $\frac{m}{\omega_c}$ than squares, where

$$\phi(\omega_c) = \frac{r_a\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a\omega_c^2(C_a + C_{ga})^2\right\}} \quad (22)$$

and
$$a = \frac{r_a^2\omega_c^2(C_a + C_{ga})^2}{\left\{\left(1 + \frac{r_a}{R_a}\right)^2 + r_a^2\omega_c^2(C_a + C_{ga})^2\right\}} \quad (23)$$

Writing (17)

$$E_g = \frac{\omega L}{r}\frac{E}{A} \quad \ldots \quad \ldots \quad (24)$$

we have

$$\begin{aligned}A^2 &= \left(1 - \frac{\mu_2\omega^3L^2C_{ga}}{r}\right)^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2L^2}{\omega_c^4r^2}\\ &= \left(1 + \frac{\phi(\omega)\omega^4L^2C_{ga}}{r}\right)^2 + \frac{\omega^2(\omega^2 - \omega_c^2)^2L^2}{\omega_c^4r^2}\\ &= \left[1 + \frac{\phi(\omega_c)\omega_c^4L^2C_{ga}}{r}\left(1 + \frac{m}{\omega_c}\right)^4\left\{1 - 2a\frac{m}{\omega_c} - a(1 - 4a)\frac{m^2}{\omega_c^2}\right\}\right]^2\\ &\quad + \frac{\omega_c^2L^2}{r^2}\left(1 + \frac{m}{\omega_c}\right)^2\left(2\frac{m}{\omega_c} + \frac{m^2}{\omega_c^2}\right)^2\end{aligned}$$

Putting

$$(r + \phi(\omega_c)\omega_c^4L^2C_{ga}) = r_0 \quad \ldots \quad \ldots \quad (25)$$

and neglecting higher powers of $\frac{m}{\omega_c}$ than squares, we obtain

$$\begin{aligned}A^2 &= \left[\frac{r_0}{r} + \left(\frac{r_0}{r} - 1\right)\left\{2(2 - a)\frac{m}{\omega_c} + (6 - 9a + 4a^2)\frac{m^2}{\omega_c^2}\right\}\right]^2 + \frac{4\omega_c^2L^2}{r^2}\frac{m^2}{\omega_c^2}\\ &= \frac{r_0^2}{r^2}\left[1 + 4(2 - a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c} + \left\{2(6 - 9a + 4a^2)\left(1 - \frac{r}{r_0}\right) + 4(2 - a)^2\left(1 - \frac{r}{r_0}\right)^2 + 4\frac{\omega_c^2L^2}{r_0^2}\right\}\frac{m^2}{\omega_c^2}\right]\end{aligned}$$

Now a is essentially less than unity, so that

$$\left\{2(6 - 9a + 4a^2)\left(1 - \frac{r}{r_0}\right) + 4(2 - a)^2\left(1 - \frac{r}{r_0}\right)^2\right\}$$

is in any case less than 28. In general, too, a will be only slightly less than unity, which would make the value of the above expression less than 6, and usually considerably less, since $\left(1 - \frac{r}{r_0}\right)$ is essentially less than unity.

On the other hand, $\frac{4\omega_cL^2}{r_0^2}$ is, in general, very large, of the order 1000 at the very least, so

that only a very small error can be introduced by neglecting the above terms in the coefficient of $\frac{m^2}{\omega_c^2}$, an error, in fact at the most only of the order $\frac{r_0^2}{\omega_c^2 L^2}$ compared with unity.

We can therefore put

$$A^2 = \frac{r_0^2}{r^2}\left\{1 + 4(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega} + 4\frac{\omega_c^2 L^2}{r_0^2}\frac{m^2}{\omega_c^2}\right\}$$

so that

$$\frac{1}{A} = \frac{r}{r_0}\left\{\left(1 + 4\frac{m^2L^2}{r_0^2}\right) + 4(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}\right\}^{-\frac{1}{2}}$$

$$= \frac{r}{r_0}\left(1 + 4\frac{m^2L^2}{r_0^2}\right)^{-\frac{1}{2}} \left\{1 + \frac{4(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\}^{-\frac{1}{2}}$$

Now

$$\frac{m}{\omega_c}\Big/\left(1 + 4\frac{m^2L^2}{r_0^2}\right) = \frac{m}{\omega_c}\Big/\left(1 + 4\frac{\omega_c^2L^2}{r_0^2}\frac{m^2}{\omega_c^2}\right),$$

which cannot be greater than $\frac{r_0}{4\omega_c L}$. Since $4(2-a)\left(1 - \frac{r}{r_0}\right)$ is essentially less than 8, and usually less than 4, owing to a being, in general, only slightly less than unity, the term involving $\frac{m}{\omega_c}$ in the expression for $\frac{1}{A}$ is less than $\frac{2r_0}{\omega_c L}$, usually less than $\frac{r_0}{\omega_c L}$. We have already neglected terms of the order $\frac{r^2}{\omega_c^2 L^2}$ compared with unity, and $\frac{r_0^2}{\omega_c^2 L^2}$ will not be of a higher order of magnitude than $\frac{r^2}{\omega_c^2 L^2}$. We can, therefore, safely neglect terms of the order $\frac{r_0^2}{\omega_c^2 L^2}$ compared with unity, and therefore obtain finally

$$\frac{1}{A} = \frac{r}{r_0}\left(1 + 4\frac{m^2L^2}{r_0^2}\right)^{-\frac{1}{2}} \left\{1 - \frac{2(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\}$$

Hence, from (24),

$$E_g = \frac{\omega_c L}{r_0}\left(1 + 4\frac{m^2L^2}{r_0^2}\right)^{-\frac{1}{2}}\left(1 + \frac{m}{\omega_c}\right) \left\{1 - \frac{2(2-a)\left(1 - \frac{r}{r_0}\right)\frac{m}{\omega_c}}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\}E$$

Since we have seen that the expression involving $\frac{m}{\omega_c}$ in the last factor is always less than $\frac{r_0}{\omega_c L}$, we can clearly neglect the term involving $\frac{m^2}{\omega_c^2}$, and so obtain finally

$$\left.\begin{aligned} E_g &= \frac{\left(1 + B\frac{m}{\omega_c}\right)}{\sqrt{1 + 4\frac{m^2L^2}{r_0^2}}}\frac{\omega_c L}{r_0}E \\ \text{where} \\ B &= \left\{1 - \frac{2(2-a)\left(1 - \frac{r}{r_0}\right)}{\left(1 + 4\frac{m^2L^2}{r_0^2}\right)}\right\} \end{aligned}\right\} \quad \ldots (26)$$

$B\frac{m}{\omega_c}$ will always differ from $\frac{m}{\omega_c}$ only by a quantity less than $\frac{r_0}{\omega_c L}$.

We can now compare the case of an actual detector valve with that of a hypothetical valve having no appreciable anode-grid capacity. In the latter case, by (25), $r_0 = r$, so that $B = 1$.

Hence in this case

$$E_g = \frac{\left(1 + \frac{m}{\omega_c}\right)}{\sqrt{1 + 4\frac{m^2L^2}{r^2}}}\frac{\omega_c L}{r}E$$

Except, therefore, for the small difference due to the fact that in the case of an actual valve $B\frac{m}{\omega_c}$ is equal to $\frac{m}{\omega_c}$ plus a quantity less than $\frac{r_0}{\omega_c L}$, the effect of the anode-grid capacity is only to increase the resistance of the input circuit from r to r_0. This reduces distortion by reducing the extent to which the side bands are cut off.

So far, therefore, as the effect of the feed-back on the *amplitude* of the side bands is

concerned, it is clear that no distortion of any significant amount is produced, but that, on the contrary, quality tends to be improved by the flattening of the resonance curve due to an increase in the effective resistance of the input circuit.

We must next determine the effect on the phase shift of the side-bands.

Evaluation of Phase Shift in Terms of $\frac{m}{\omega_c}$.

The angle θ represents the phase difference between the grid-filament potential difference and the E.M.F. acting in the input circuit. What we have to find, however, is the phase shift between the side-bands and the carrier wave component of the potential difference. Denoting this phase shift by ϕ, we have $\phi = (\theta - \theta_c)$, where θ_c denotes the value of θ for the carrier-wave frequency.

From (18) we have

$$\tan \theta_c = \frac{\omega_c L}{-r}.$$

Thus the feed-back produces no phase shift of the carrier-wave at all.

Putting $(r - \mu_2 \omega \omega_c^2 L^2 C_{ga}) = R$, we find from (18)

$$\tan \phi = \tan (\theta - \theta_c)$$

$$= \frac{\left[\dfrac{\omega L R}{-r\left\{R - \dfrac{(\omega^2 - \omega_c^2)L^2}{r}\right\}} - \dfrac{\omega_c L}{-r}\right]}{\left[1 + \dfrac{\omega\omega_c L^2 R}{r^2\left\{R - \dfrac{(\omega^2 - \omega_c^2)L^2}{r}\right\}}\right]}$$

$$= \frac{-\left\{(\omega - \omega_c)\dfrac{LR}{r} + \dfrac{\omega_c(\omega^2 - \omega_c^2)L^3}{r^2}\right\} r}{\left\{\dfrac{R}{r}(r^2 + \omega\omega_c L^2) - (\omega^2 - \omega_c^2)L^2\right\}}$$

which, on neglecting r^2 compared with $\omega\omega_c L^2$, reduces to

$$\tan \phi = \frac{-\left\{\dfrac{R}{r} + \dfrac{\omega_c(\omega + \omega_c)L^2}{r^2}\right\}\left(\dfrac{r}{\omega_c L}\right)\dfrac{m}{\omega_c}}{\left\{\dfrac{R}{r}\dfrac{\omega}{\omega_c} - \left(\dfrac{\omega^2}{\omega_c^2} - 1\right)\right\}}.$$

Substituting for $\phi(\omega)$ from (21), and neglecting higher powers of $\frac{m}{\omega_c}$ than squares, we have

$$R = (r - \mu_2 \omega \omega_c^2 L^2 C_{ga})$$

$$= (r + \phi(\omega)\omega^2\omega_c^2 L^2 C_{ga})$$

$$= \left\{r + \phi(\omega_c)\omega_c^4 L^2 C_{ga}\left(1 + \frac{m}{\omega_c}\right)^2 \left(1 - 2a\frac{m}{\omega_c} - a(1 - 4a)\frac{m^2}{\omega_c^2}\right)\right\}$$

$$= \left\{r + \phi(\omega_c)\omega_c^4 L^2 C_{ga}\left(1 + 2(1 - a)\frac{m}{\omega_c} + (1 - a)(1 - 4a)\frac{m^2}{\omega_c^2}\right)\right\}$$

$$= r_0\left\{1 + \left(1 - \frac{r}{r_0}\right)(1 - a)\left(2\frac{m}{\omega_c} + (1 - 4a)\frac{m^2}{\omega_c^2}\right)\right\}$$

Substituting for R in the expression for $\tan \phi$, we obtain

$$\tan \phi = \frac{-\left\{1 + \left(1 - \dfrac{r}{r_0}\right)(1 - a)\left(2\dfrac{m}{\omega_c} + (1 - 4a)\dfrac{m^2}{\omega_c^2}\right) + \left(2 + \dfrac{m}{\omega_c}\right)\dfrac{\omega_c^2 L^2}{r r_0}\right\}\left(\dfrac{r_0}{\omega_c L}\right)\dfrac{m}{\omega_c}}{\left[\dfrac{r_0}{r}\left(1 + \dfrac{m}{\omega_c}\right)\left\{1 + \left(1 - \dfrac{r}{r_0}\right)(1 - a)\left(2\dfrac{m}{\omega_c} + (1 - 4a)\dfrac{m^2}{\omega_c^2}\right)\right\} - \left(2\dfrac{m}{\omega_c} + \dfrac{m^2}{\omega_c^2}\right)\right]}$$

$$= \frac{-\left[\left(2 + \dfrac{m}{\omega_c}\right) + \left\{1 + \left(1 - \dfrac{r}{r_0}\right)(1 - a)\left(2\dfrac{m}{\omega_c} + (1 - 4a)\dfrac{m^2}{\omega_c^2}\right)\right\}\dfrac{r r_0}{\omega_c^2 L^2}\right]\dfrac{mL}{r_0}}{\left[1 + \left\{\left(1 - 2\dfrac{r}{r_0}\right) + 2(1 - a)\left(1 - \dfrac{r}{r_0}\right)\right\}\dfrac{m}{\omega_c} + \left\{(4 - 7a + 4a^2)\left(1 - \dfrac{r}{r_0}\right) - \dfrac{r}{r_0}\right\}\dfrac{m^2}{\omega_c^2}\right]}.$$

We can neglect, compared with the terms $\left(2 + \frac{m}{\omega_c}\right)$, the terms in the numerator which are multiplied by the very small quantity

$\frac{rr_0}{\omega_c^2 L^2}$, while the denominator may be written $\left(1 + b_1 \frac{m}{\omega_c} + b_2 \frac{m^2}{\omega_c^2}\right)$, where b_1, b_2 are clearly comparable with unity, so that

$$\tan \phi = -\left(2+\frac{m}{\omega_c}\right)\left(1+b_1 \frac{m}{\omega_c} + b_2 \frac{m^2}{\omega_c^2}\right)^{-1} \frac{mL}{r_0}$$

$$= -\left(2+\frac{m}{\omega_c}\right)\left\{1-b_1 \frac{m}{\omega_c} + (b_1^2 - b_2)\frac{m^2}{\omega_c^2}\right\}\frac{mL}{r_0}$$

neglecting higher powers of $\frac{m}{\omega_c}$.

Therefore, finally,

$$\left.\begin{aligned} \tan \phi &= -\left(1 + \beta \frac{m}{\omega_c} + \gamma \frac{m^2}{\omega_c^2}\right)\frac{2mL}{r_0} \\ &\text{where} \\ \beta &= \left(\frac{1}{2} - b_1\right) = \left\{\frac{3}{2} - 2(2-a)\left(1-\frac{r}{r_0}\right)\right\} \\ &\text{and} \\ \gamma &= \left(b_1^2 - \frac{1}{2}b_1 - b_2\right) = \left\{\frac{5}{2} - (15-12a \right. \\ &\quad \left. + 4a^2)\left(1-\frac{r}{r_0}\right) + 4(2-a)^2\left(1-\frac{r}{r_0}\right)^2\right\} \end{aligned}\right\} \quad (27)$$

Since usually a will only be slightly less than unity, β will not differ much from

$$\left\{\frac{3}{2} - 2\left(1 - \frac{r}{r_0}\right)\right\},$$

nor γ from

$$\left\{\frac{5}{2} - 7\left(1 - \frac{r}{r_0}\right) + 4\left(1 - \frac{r}{r_0}\right)^2\right\},$$

so that β and γ will not differ by more than about .2 and 3 from the values, $\frac{3}{2}$ and $\frac{5}{2}$, which they have in the case of a valve with negligible anode-grid capacity. Consequently, so far as is indicated by the factor

$$\left(1 + \beta \frac{m}{\omega_c} + \gamma \frac{m^2}{\omega_c^2}\right),$$

the feed-back does not produce any large percentage change in the phase shift of the side-bands. A greater possible change of phase shift is indicated by the factor $\frac{2mL}{r_0}$, but as r_0 is essentially greater than r, this change is always in the direction of decreasing the amount of the phase shift, and this to an equal extent for both positive and negative corresponding side-bands.

Thus, in so far as the feed-back causes an increase of the effective resistance of the input circuit, it decreases any distortion which may arise from phase shift of the side-bands, of which phase shift there is always a certain amount present.

(*To be concluded.*)

Professor Heinrich Barkhausen, photographed on the occasion of a visit to the laboratory of Baron Manfred von Ardenne in Berlin.

Further Notes on the Calibration Permanence and Overall Accuracy of the Series-gap Precision Variable Air Condenser.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

(Concluded from page 30 of January issue.)

Part II.

A Final Consideration of Overall Constancy.

In Fig. 12 the curve of capacity change due to plate tilting calculated for a moving plate having an intersection capacity of $2.5\mu\mu F$. will be found to be about half that

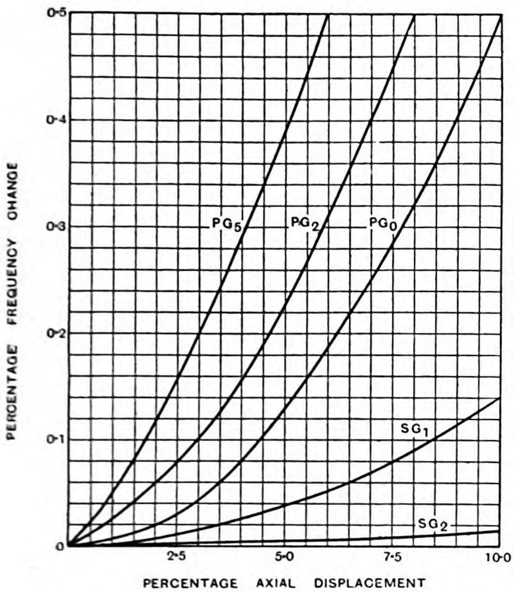


Fig. 17.

obtained experimentally for a purely axial displacement. A curve giving the error due to this latter defect was given in a previous article* and is reproduced here for the purpose of comparison (Fig. 17, curve SG_2).

Allowing therefore for the possibility of a post-calibration displacement of the whole moving system relative to the fixed system amounting to 5 per cent. purely axial displacement *plus* 5 per cent. tilting or "incline displacement" the resultant consequent change of capacity, it would seem, would certainly be less than 1 part in 5,000 (1 part in 10,000 in frequency).

The temperature coefficient of capacity of this condenser is always less than that of a precision fixed value air condenser—very appreciably less for the higher scale readings. The temperature coefficient of a *good quality* fixed air condenser (assuming that the contribution to this factor by the insulating mounting is sensibly zero) is positive by the amount of the coefficient of *surface* expansion of the metal from which the conductor plates are constructed and negative by the amount of the coefficient of *linear* expansion of the material of the spacing washers.

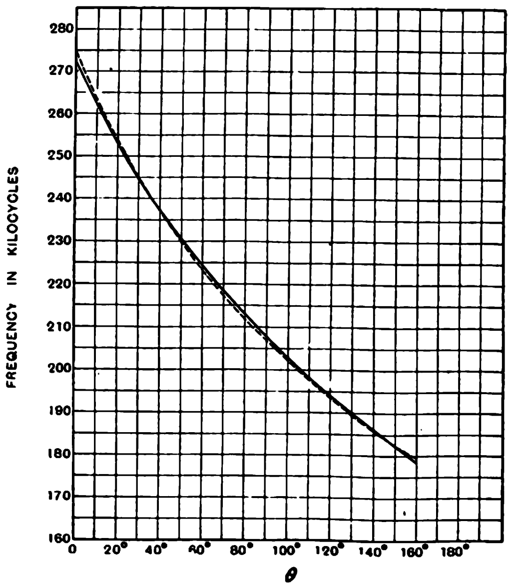


Fig. 18.

The resultant temperature coefficient of capacity is therefore of the order + 0.00001 per degree Fahrenheit (the temperature coefficient of linear expansion of ordinary metals).

* "The Demonstration of a New Precision Wavemeter Condenser," *E.W. & W.E.*, May, 1928.

In the series-gap variable condenser, since glass or similar material is employed for the moving plate, the negative component of temperature coefficient may be made to compensate for the positive component. In order to make sure that the temperature coefficient has the lowest possible value throughout the range of the condenser its value at the maximum capacity setting should be made sensibly zero by a slight adjustment of the ratio of the moving plate thickness to the dimension of the dielectric air gap.

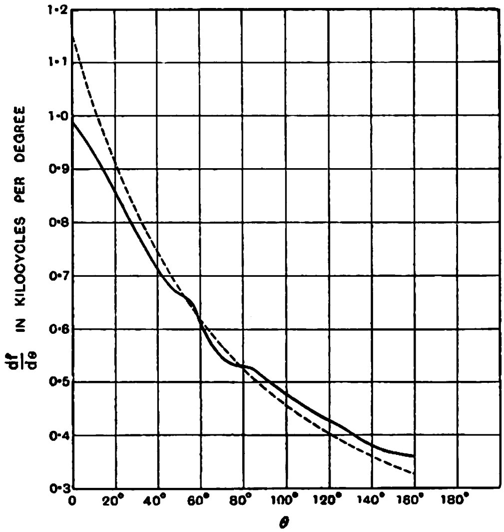


Fig. 19.

Let R be this ratio and x, y and z be the temperature coefficients of linear expansion of fixed plates, spacers and moving plates respectively, then equating positive and negative coefficients

$$2x = y + 0.5R\,(y - z).$$

from which

$$R = \frac{2(2x - y)}{y - z}$$

approximately for zero temperature coefficient of capacity at its maximum setting.

This assumes that the conducting area of the moving plate extends *very* slightly beyond the boundaries of the fixed plates, a condition which is also advantageous in reducing the field through the insulating material of the moving plate and in increasing the ratio of maximum to minimum capacity if the fixed plate supports are kept well away from the outer edge of the moving plate.

Fortunately, in practice, the gap and plate dimensions are such that this temperature coefficient condition is approximately satisfied. The temperature coefficient at lower capacity settings will, of course, be greater, but even at minimum capacity it will be slightly less than that of a good quality fixed air condenser.

It is seen, therefore, that with a temperature coefficient less than 1 part in 10^5 a temperature variation of 20 deg. F. will not necessitate a calibration correction even for the most accurate sub-standard work.

Methods of Interpolation.

That the reading or setting of the scale will not limit the accuracy of the condenser has already been shown in the previous articles, but mention should, it is thought, be made here of the possible methods of interpolation which can be employed between the points for which a calibration exists.

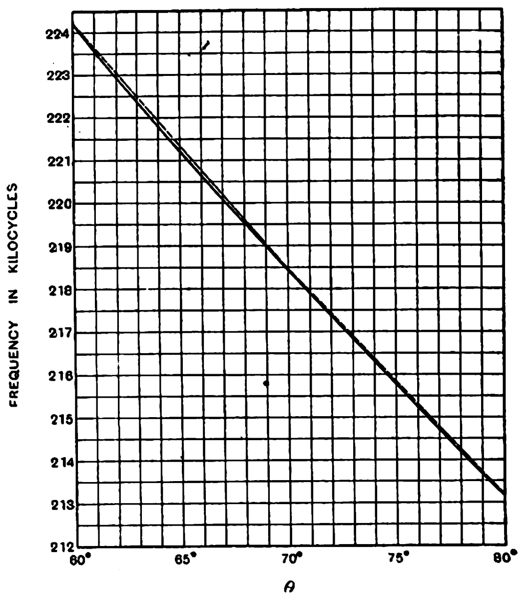


Fig. 20.

Although not impossible it would obviously be costly to construct a series-gap variable condenser so perfectly that its degree of conformity to a linear law of capacity change was of a sufficiently high order to

permit linear capacity interpolation between adjacent calibrated points without impairing the high degree of overall accuracy (constancy) obtainable with such a condenser.

If departures from a linear law are present the condenser must be calibrated in terms

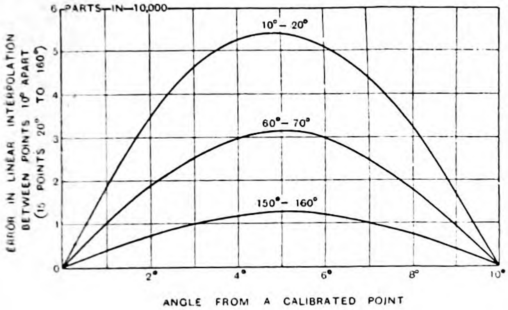


Fig. 21.

of frequency at a fairly large number of points (say at about every 10 deg. of its scale of 180 deg., although preferably at exact kilocycle multiples) and a curve of $df/d\theta$ plotted against degree scale reading θ in order to ascertain the variations of law.

Fig. 18 gives a frequency calibration curve for a single range of a wavemeter whose variable condenser has a slope variation of about 15 per cent. throughout its range, the dotted curve of the same figure is the corresponding curve for a truly linear variable condenser.

In Fig. 19 are plotted curves of $df/d\theta$ for these actual and ideal condensers.

The values of $df/d\theta$ are, of course, obtained from the differences between successive calibrated points and are plotted at scale readings midway between such points.

In a wavemeter of many ranges one range could, with little extra cost, be calibrated at a larger number of points than the remainder in order to determine with accuracy the $df/d\theta$ curve which will then have the same characteristics for all ranges.

The exact frequency at any setting of the condenser can now be determined by finding from such a curve the value of $df/d\theta$ corresponding with a point on the degree scale midway between that setting and the nearest calibrated point (f_1) lower on the degree scale and simply computing the required frequency from :

$$f_x = f_1 - \beta \frac{df}{d\theta}$$

where β is the angular difference between the two settings f_x and f_1.

In order to obtain accurate interpolation without computation the frequencies obtained in this manner can, of course, be plotted on large scale curves, such as that of Fig. 20, a curve embracing three calibrated points and extending therefore over 20 deg. of the condenser scale only. The full line curve shows an interpolation curve plotted from the full line $df/d\theta$ curve of Fig. 19. The dotted curve of the same figure shows how closely approximate a linear interpolation may be if the adjacent calibrated points are sufficiently close (10 deg. in the present example).

For linear interpolation, of course, $df/d\theta$ is assumed to be constant between calibrated points and to have the value :—

$$k = \frac{f_1 - f_2}{\alpha}$$

where f_1 and f_2 are the frequencies of the adjacent calibrated points and α the angle

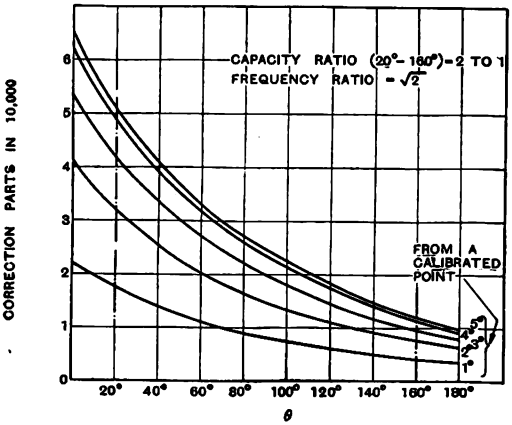


Fig. 22.—*If linear interpolation between adjacent calibration points 10° apart is employed the correction given must be subtracted from the frequency reading.*

between their degree scale settings. The frequency of the required setting is then

$$f_x = f_1 - k\beta \text{ approximately.}$$

The maximum errors introduced by this linear method of approximate interpolation in the present example are about 4 parts in 10,000 between 60 deg. and 70 deg. and about 1 part in 10,000 between 70 deg. and 80 deg., the two maximum errors being greatly different owing to the considerable

irregularity of the $df/d\theta$ curve at this part of the scale.

Linear Interpolation. Approximations—and Corrections.

If a good quality variable condenser is employed in a wavemeter the errors introduced by linear interpolation are always of

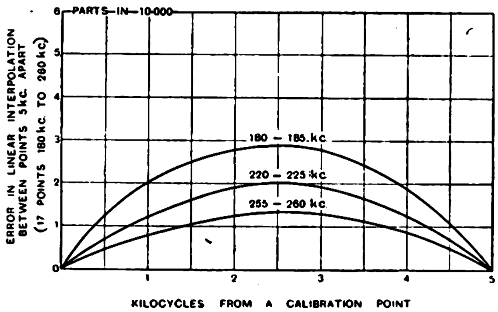


Fig. 23.

this order if the total frequency change per range is not too great and if the calibration points are not too infrequent. This fact may be made to save much labour in the plotting of large scale interpolation curves of frequency such as that of Fig. 20, by merely drawing straight lines between successive calibration points instead of obtaining many interpolated points for the correct curve from a curve of $df/d\theta$. The frequency read from such a linear interpolated curve will, of course, need correction for work of the greatest accuracy. The correction required will vary with the distance from the point being read to the nearest point for which a calibration exists, as is shown well by the curves of Fig. 21. These curves give the necessary correction for various portions of the scale of a wavemeter whose ratio of maximum to minimum capacity per range (at 20 deg. and 160 deg.) is 2 to 1 and whose calibration has been effected at intervals of 10 deg. The same corrections are shown in a more complete manner in Fig. 22.

These curves are, of course, characteristic of the variable condensers of the wavemeter and will vary in shape with variations in its law. Those given in Figs. 21 and 22 are for a perfectly linear relationship between *capacity* and degree scale reading. If the condenser law is imperfect these curves will themselves be irregular in shape, but the important point to note is that they will be constant in shape for all ranges of the wavemeter in which the particular condenser is used and only one set of correction curves need therefore be plotted. Moreover, no great accuracy is needed in plotting correction curves.

For S.L.C. condensers, if the wavemeter is calibrated at equal frequency intervals instead of at equal angular intervals, the variation in the correction necessary at different parts of the scale is much reduced, even though the total number of calibrated points per range is approximately the same

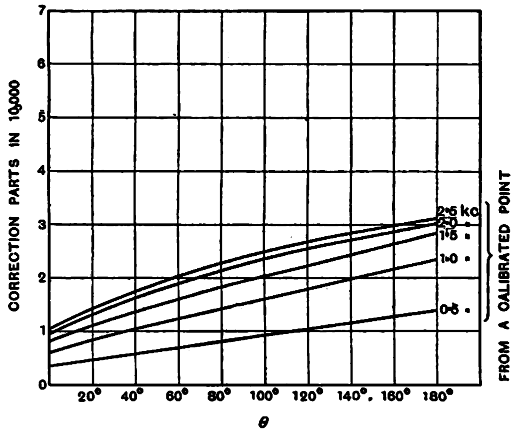


Fig. 24.

in each case. This is shown by the curves of Figs. 23 and 24 for the same case as that of Figs. 21 and 22 and plotted to the same scale of correction for comparison with them, the only difference being that 17 calibration points of equal frequency intervals were employed instead of 15 of equal angular intervals.

The difficulty with correction for a uniform frequency interval calibration is that of making one set of correction curves serve for all ranges of the wavemeter. This can be overcome to a great extent if approximately the same number of calibration points are obtained on each range, in which case the set of curves as those of Fig. 24 will be approximately true for distances from calibration points proportionally similar on all ranges.

The Physical Society's Exhibition.

Matters of Wireless and Laboratory Interest.

THE Nineteenth Annual Exhibition of the Physical Society and the Optical Society was held this year at the Imperial College of Science and Technology on 8th, 9th and 10th January. The Exhibition again lived up to the reputation which it has acquired in recent years of being perhaps the most important display of the year from the point of view of laboratory and measurement interests, both wireless and general.

ELECTRICAL MEASURING INSTRUMENTS.

Electrical measuring instruments, *e.g.*, Ammeters, Voltmeters, Milliammeters, etc., were, as usual, in considerable number, and while there was little of very striking novelty, the instruments on view were typical of the modifications and refinements effected in design and manufacture since the last Exhibition.

Rectifier instruments in which an ordinary moving coil D.C. instrument is used in conjunction with a copper oxide rectifier for A.C. measurements at commercial frequencies, were on display by EVERETT EDGCUMBE & Co., LTD., and by FERRANTI, LTD. The notable feature of these instruments is, of course, their uniformity of scale as compared with the usual types of A.C. instrument. EVERETT EDGCUMBE had these available down to 1 mA for full scale, and FERRANTI, LTD. down to 1.5 mA and one volt, in their small pattern, and up to 500 volts in a larger size.

Another new feature of the former firm was a Synchronous Time Interval Meter, for measurement of short time intervals ranging from 1/20th second upwards.

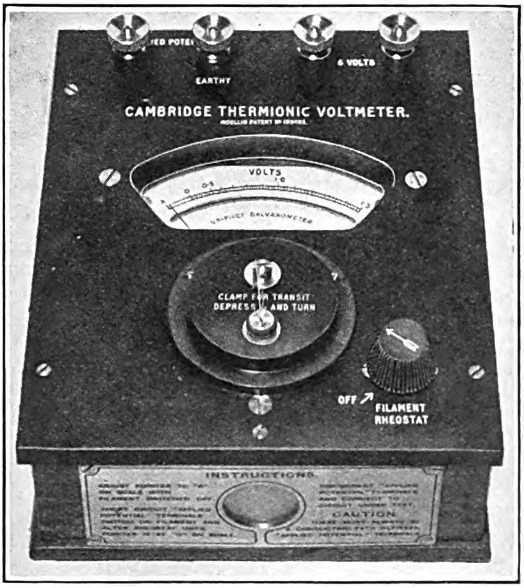
In addition to the rectifier instruments, FERRANTI, LTD., had on view a large range of instruments of wireless and general interest. Their now well-known 2½-inch instrument was shown in various forms for D.C., while they had also on view instruments of thermal pattern employing a non-contact thermo-couple in conjunction with this movement for A.C. of all frequencies. The thermo-junction pattern was also available in a 4-inch dial instrument. Various switchboard instruments were also on view, while another exhibit was the valve tester which was shown at the last Radio Exhibition at Olympia. A very interesting instrument was a multirange D.C. test set, which provides very complete D.C. measuring facilities on small compass. Without extra apparatus the lower current range is down to 1 mA., and the highest voltage range up to 500 V., while leads and accessories are available for use of this as a valve tester.

At the stand of CROMPTON PARKINSON, LTD., an A.C. Test Portable Multirange Ammeter and Multirange Voltmeter, shown for the first time last year, was again on view with various new attachments, increasing its utility and scope.

ELLIOTT BROS. showed precision instruments of various patterns, moving iron and dynamometer, and a range of miniature instruments suitable for many wireless purposes. Another feature of wireless interest was vacuum junctions of various ranges with the heater insulated from the couple.

EVERSHED & VIGNOLES, LTD., showed various forms of their well-known resistance testing apparatus and a number of recording instruments both of portable and switchboard pattern.

NALDER BROS & THOMPSON, LTD., had on view a large range of first-grade induction instruments, notable for a very large (nearly circular) scale, while a laboratory standard pattern instrument was shown in dynamometer type for A.C. and D.C. and in permanent-magnet moving-coil type for D.C. only, the accuracy being 0.1 per cent.



Cambridge unipivot thermionic voltmeter.

Circular scale D.C. instruments of the "Cirscale" pattern were on view at the stand of the RECORD ELECTRICAL Co., LTD., who also showed a "change coil" ammeter covering 0–600 amps. in six consecutive steps and giving accurate readings on D.C. and A.C. at commercial frequencies.

The WESTON ELECTRICAL INST. Co., LTD., showed the usual wide range of instruments to be expected from this firm. Their laboratory standard instrument, moving coil for D.C. and dynamometer for D.C. or A.C., is a well-known feature, while standard portable testing instruments were shown

in wide variety. Portable testing instruments for radio service were well represented, both in A.C. and D.C. patterns, while this company's Direct Reading Valve Tester (shown last year) was also again on view.

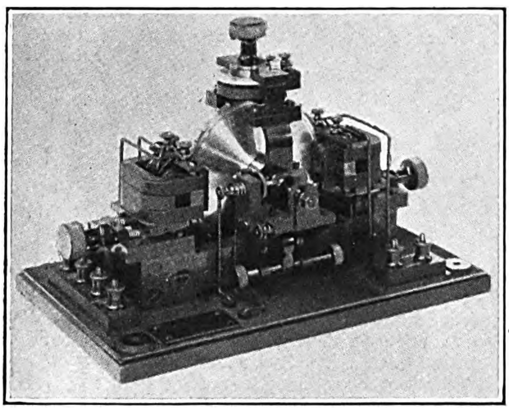
LABORATORY EQUIPMENT.

The customary excellent display of laboratory apparatus was again a marked feature, and several new and interesting instruments were on view.

THE CAMBRIDGE INSTRUMENT CO., LTD., had on view a recording potentiometer, capable of application to many purposes of low-power recording. The instrument was actually shown in the form of a Recording Gas Calorimeter, and also of a Frequency Recorder over the range 46–54 cycles. Another new instrument of this firm was the Campbell A.C. potentiometer—a development of the Larsen type of potentiometer—permitting the measurement of unknown A.C. voltage in terms of its inphase and quadrature components with reference to a fixed standard. Other attractive exhibits were thermionic (Moullin) voltmeters in various ranges, an improved Paschen galvanometer, a self-contained Wheatstone bridge in three or four decades, and a new decade resistance box using a new system of winding for the minimising of residual inductance. Various other instruments of industrial application were also on view incorporating modifications and improvements effected during the past year.

In addition to the instruments already noted, CROMPTON PARKINSON, LTD., had on view their well-known Standard Potentiometer Equipment, also a potentiometer of sub-standard grade, and many other articles—bridges, galvanometers, etc.—of laboratory use.

G. CUSSONS, LTD. (Manchester) showed a Fractional Chronograph, demonstrated in operation. While usually supplied to mark 1/50th second, a 3-speed gear enables two other definite time values

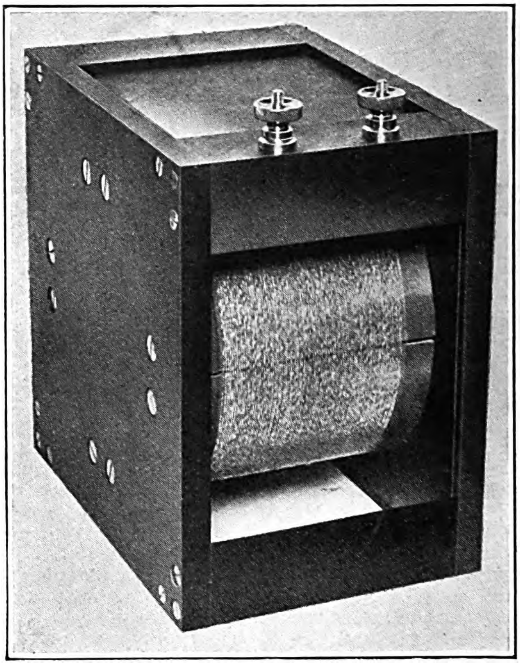


Sullivan valve-driven phonic wheel for determining the frequency of a standard fork.

to be obtained, while it is stated that the instrument can be supplied, if required, to record intervals of 1/1000th second.

W. EDWARDS & CO., showed vacuum pumps of various pattern, gauges and other vacuum-working accessories, and a complete range of modern types of photo-electric cell.

GAMBRELL BROS., LTD., devoted part of their display to high tension bridges and accessories for



Special type inductance for standard wavemeters, shown by H.W. Sullivan.

work of this type. Other instruments exhibited were a Kelvin Bridge and a Laboratory Variable Condenser.

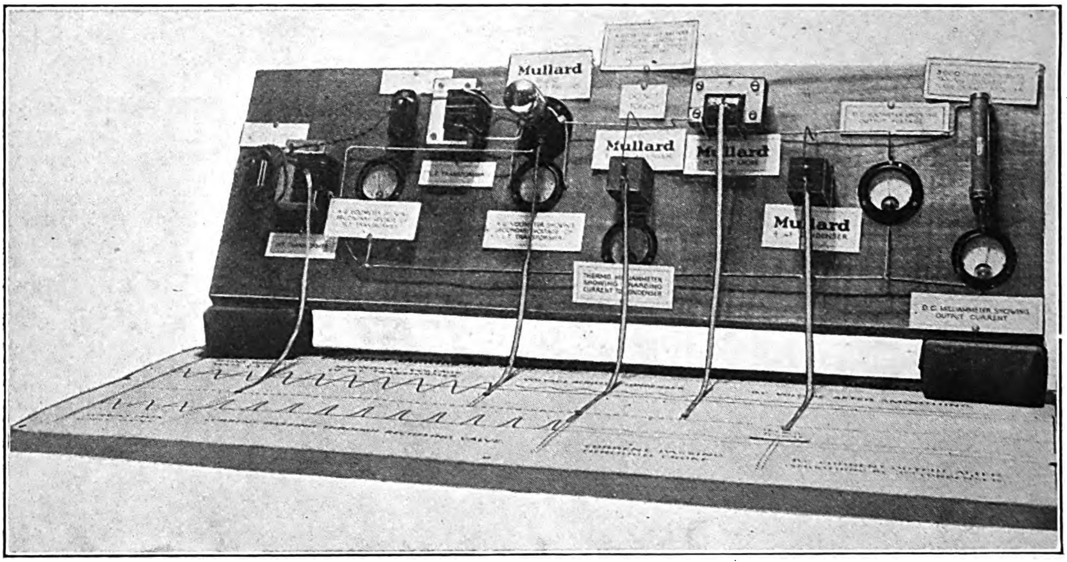
J. J. GRIFFIN & BAIRD & TATLOCK, LTD., showed the "Microid" Adaptable Galvanometer in a universal model and in a sensitive model. The former may be used vertically or horizontally. Other forms of laboratory galvanometer—Ayrton Mather and d'Arsonval—were also on view.

ADAM HILGER were showing the Holweck High-Vacuum Pump, which has been used in conjunction with the Holweck demountable valve and also with the Holweck demountable cathode-ray oscillograph.

W. G. PYE & CO., of Cambridge, had a considerable display of useful laboratory apparatus, including such articles as electrically maintained forks, phonic-wheel motors, potentiometers, bridges, etc.

H. W. SULLIVAN, LTD., made a very extensive exhibit of apparatus for both radio and audio frequency work. Among the radio frequency was the Standard Multivibrator Wavemeter and a highly accurate 1,000-cycle fork for use with it. A phonic wheel and amplifier for standardisation check of the fork was also on view, the total exhibit being a prominent display of high frequency standard technique. The latest form of Sullivan-

exhibition at the stand of the associated Marconiphone Co., Ltd., where were also a large range of new receivers, such as Model 23A, a self-contained 2-valve set with cone loud speaker; Model 35, a 3-valve set (one screened) with pentode output, and Model 44, a 4-valve set using two screened-grid valves. A very complete display of transmitting, modulating and rectifying valves in glass and silica were on view with a high power metal-glass valve of input up to 30 kW. An equally representative collection of P.M. receiving valves included screened-grid valves, "Pentones" and a



A demonstration H.T. eliminator for A.C. mains shown by Mullards. Meters in the various circuits indicate amplitude of A.C. and D.C. components.

stages. Power units for A.C. and D.C. mains were also available in many types, including models applicable to any 2- or 3-valve sets for complete elimination of batteries. Moving-coil and cone loud speakers were also shown, as well as a large range of components, including transformer variable condensers, short wave coils, etc.

Marconi's Wireless Telegraph Co., Ltd., had a large display of gear for both maritime and aircraft purposes. Amongst the former were two D.F. sets one (D.F.M. 4) primarily for naval purposes, arranged for bridge operation or for handling by unskilled wireless personnel, and the other (Type 11G.) for mercantile marine use, capable of working up to 250 miles from a $1\frac{1}{2}$ kW. coast station. The Marconi Type Rg. 18 Receiver is also primarily for naval purposes, while another marine exhibit was this Company's Automatic Alarm Device. Aircraft Type A.D.18 set provides telegraph or telephone send/receive facilities for 2-seater or larger aircraft. A signal strength measuring set was also on view for 14–5,000 m.

The Radio Communication Co., Ltd., displayed their new design of marine D.F. set. The frame aerial is enclosed in a chromium-plated copper tube and mounted on a deck pedestal. A supersonic receiver of five valves has very simple controls, the whole being arranged for the minimum of technical skill in operation.

The joint display of the Mullard Radio Valve, Co., Ltd., and of the Mullard Wireless Service Co., Ltd., was naturally chiefly connected with number of low impedance rectifiers for eliminator use. The Holweck pump was also on display at this stand. A demonstration of a short-wave generator at a frequency of about 100 megacycles was on view working to a Lecher wire system and showing nodes and antinodes along the wires, while another interesting demonstration was that of a wireless amplifier dissected and showing the functions of each part of the system, measuring instruments indicating the various voltages present.

Shimwell, Alexander & Co., displayed the Codd cell which was exhibited last year in the Research Section. This cell is of the single fluid type, with zinc-carbon electrodes and ferric chloride depolariser. Cells of this pattern were shown in sizes of 36–144 ampere hour capacity, for L.T. and like purposes, and in a 6 a.h. size for H.T. supply.

In addition to the laboratory apparatus already mentioned Gambrell Bros., Ltd., showed new models of their mains receivers (D.C. and A.C.), some incorporating screened valves.

The Dubilier Condenser Co., Ltd., showed a very large range of condensers for all wireless purposes, including smoothing condensers and condensers for various transmitter purposes. H.F. Chokes, Toroidal Coils, H.T. supply units and smoothers were also on display.

The exhibits of the Igranic Electric Co., Ltd., were almost entirely wireless. Various receivers and receiver outfits were on view, these including a screened-grid short-wave receiver, using

H.F. amplification down to 10 m.; the Neutro-Regenerative Short Wave Receiver covering 15 to 20,000 m., the Igranic Universal Portable Receiver and the Igranikit Outfit for home construction, the latter being available in both A.C. and battery models. A considerable section was devoted to gramophone pick-ups and associated devices, while an interesting range of transformers of various kinds included the "Pentoformer," designed for best volume and quality in the last stage using a pentode valve. Wire-wound variable resistances of 50,000 and of 250,000 ohms were also attractive features.

The MacLachlan-Sullivan Wavemeter, already described under H. W. SULLIVAN's display, should also be mentioned among wireless items.

BAKELITE, LTD., had an extensive display of mouldings, sheets, etc., of insulating material, including a new preparation "Flaked Fabric Moulding Material" which is particularly resistive to shock.

An exhibit of particular interest was that of the BRITISH METALLISING CO., LTD., showing a process of producing a metal film or coating firmly adherent to a non-metallic base, on which coating, in turn, a large range of non-ferrous metals may subsequently be plated to any desired thickness. Panels were exhibited showing four stages in the metallising and plating process, while specimen panels were on view showing the finished process with light deposits of (*a*) silver on vulcanite and (*b*) copper on vulcanite. Such panels should prove of use for many wireless and electrical purposes.

RESEARCH AND EXPERIMENTAL SECTION.

The Research and Experimental Section, inaugurated two years ago, was again a feature of the Exhibition and contained various items of wireless and allied interest.

The BRITISH THOMSON HOUSTON CO. (ENGINEERING LABORATORY) demonstrated an apparatus for tracing visual characteristics of loud speakers and amplifiers, using a calibrated condenser microphone and a beat oscillator up to 10 kc.

THE CAMBRIDGE INSTRUMENT CO. (RESEARCH DEPARTMENT) had on view a patented valve method of controlling H.T. supply and a microscopic display of welded joints for use in vacuo thermo junctions.

THE G.E.C. RESEARCH LABORATORIES showed a heterodyne low-frequency oscillator of 50 to 6,000 cycles, a sensitive electroscope and a precision variable condenser, previously exhibited in an unfinished state.

THE GRAMOPHONE CO. (RESEARCH LABORATORIES) had demonstrations of (*a*) the measurement of mechanical impedance, (*b*) a logarithmic recording galvanometer (shown plotting the electrical response characteristic of a pick-up device), (*c*) vibrations of a stretched membrane loud speaker.

THE NATIONAL PHYSICAL LABORATORY had several exhibits of wireless interest. These included :—

(a) *Dr. D. W. Dye*—a heterodyne low-frequency oscillator 10 to 10,000 cycles.

(b) *Wireless Division*—Apparatus for the recording of wireless time signals on wavelengths from 1,000 to 20,000 metres.

(c) *Wireless Division*—A portable direction finder for 50 to 2,000 metres.

(d) *Wireless Division*—Simple apparatus for rapid measurements of the capacity and power factor of variable condensers.

(e) *Wireless Division*—Mercury-in-glass coil used for investigations of high frequency resistance.

(f) *Mr. G. P. Barnard*—A demonstration of some simple practical applications of the properties of the selenium cell.

MR. E. B. MOULLIN demonstrated his new ammeter for currents of extremely high frequency, which can be calibrated by a steady current. The action of this instrument depends on measuring the force between two cylinders carrying oppositely directed currents, and a correction factor for any frequency can be determined.

DR. J. H. VINCENT showed some experiments in magneto-strictive oscillators at audio and radio frequencies. These were well demonstrated as frequency stabilising devices, a very minute high frequency rod, working at 843 kc., being a particularly interesting illustration of the use of magneto-striction.

Book Review.

DIE AUSBREITUNG DER ELEKTROMAGNETISCHEN WELLEN (The Propagation of Electromagnetic Waves). By Dr. A. Sacklowski, pp. xii. + 129, with 46 Figs. Published by Weidmannsche Buchhandlung, Berlin.

This is a review of all the work which has been published on the subject prepared by the author, who was in the Government Telegraph Department. Dr. K. W. Wagner who asked the author to undertake this compilation has contributed an introduction. The first ninety-three pages are devoted to a necessarily brief but well-arranged description of the theoretical and practical research which has been carried out on the propagation of radio waves. The last thirty-six pages contain a most useful bibliography, giving 474 references to original publications on the subject arranged alphabetically according to authors' names.

It is a most useful book of reference.

G. W. O. H.

The Design of Transmitting Aerials for Broadcasting Stations.

(Paper by Messrs. P. P. Eckersley, M.I.E.E., T. L. Eckersley, B.A., B.Sc., and H. L. Kirke, read before the Wireless Section, Institution of Electrical Engineers, on 2nd January, 1929.)

ABSTRACT.

The paper deals with the important technical aspect of the design of the transmitter aerial, and it is suggested that attention to this subject might help to improve conditions in Europe generally. Difficulties of mutual interference between stations and of the limited service area of stations indicate the need for an aerial which produces only a direct or ground ray. The indirect ray interferes with other distant stations, produces fading and bad quality in the local service area, while all energy radiated upwards is wasted, from a broadcasting point of view. The more the aerial can be made to radiate only in a direction tangential to the earth's curvature at the base of the aerial, the more will the ideal conditions be approached.

It is further important to know the rapidity at which these rays will be attenuated, and the second section of the paper deals with this subject, giving a complete set of attenuation curves for various broadcasting wavelengths.

SECTION I.

THEORETICAL CONSIDERATIONS OF THE AERIAL AS A RADIATOR.

S. Ballantine has shown* that radiation from an aerial can be resolved into radiation due to the aerial itself and radiation from an image of the aerial in the earth.

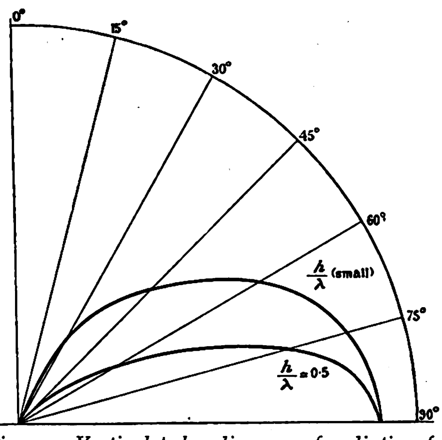


Fig. 1.—*Vertical polar diagram of radiation for ½λ and ¼λ (or less) aerials. Drawn for the same maximum radiation intensity in the horizontal plane.*

For aerials of vertical height h less than ¼λ the space phase of the element currents in the real aerial and its image will not be sufficiently different to cause cancellation of radiation in non-horizontal directions. As h is increased to ½λ, however, the maximum current I in the aerial is at a distance ½λ (180 deg.) from the maximum image current. There will be, in this case, considerable cancellation of radiations at high angles. As h is still further increased, then, provided the currents are in phase all along the aerial, the cancellation will be greater still in all directions other than the horizontal.

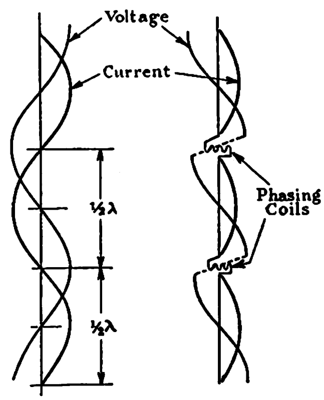


Fig. 3.—*Current and voltage in a long uniform aerial.*

Fig. 4.—*Current and voltage in a Franklin aerial.*

Fig. 1† gives vertical polar diagrams, due to Ballantine, for ¼λ and ½λ aerials for the same field strength on the ground, and assuming the earth a perfect conductor. This shows that a given field strength can be obtained by the use of a high aerial with small current or a small aerial with large current.

The field strength on the ground for a given wavelength is proportional to metre-amperes (h,I), so that for a given power we must produce a maximum value of $h,I/\lambda$. Increasing the aerial height cancels angular radiation while the ground vector remains the same, so that less total power is radiated with the high aerial for the same effect on the ground.

It is shown that the advantage of the tall aerial decreases beyond ½λ, due to the fact, illustrated in Fig. 3, that the phase reverses in the upper part of a long homogeneous aerial. The obvious correction is to add ½λ aerials one above the other, as in Fig. 4.

* *Proc. I.R.E.*, 1924, Vol. 12, p. 836.

† The author's original figure numbers are adhered to throughout this abstract.

and to introduce a "phasing-coil" to reverse the phase at each join. This device has been adopted by Franklin in his beam system for short waves.

Fig. 5 shows the relative power required to produce a given field strength for different values of $4h/\lambda$, up to 2, the curves being shown for different values of dead-loss resistance. Fig. 6 shows the increase of field strength, using different heights of aerial with the same aerial power.

Fading.—The flattening-out of the vertical polar diagram reduces the indirect ray and so should reduce fading. It is shown that the ratio of indirect ray to direct ray with a $\frac{1}{2}\lambda$ aerial is reduced, at 100 miles, to 0.05 of the ratio when using a $\frac{1}{4}\lambda$ aerial—assuming 100 km. as the height of the Heaviside layer.

Effective height.—It is known that the theoretical effective height h_1 for a $\frac{1}{4}\lambda$ aerial is $2/\pi \times$ actual height h. But it is important not to use this value for h_1 if an aerial less than $\frac{1}{4}\lambda$ in height has to be loaded by added inductance to give it the same natural wavelength as if it were a vertical wire of length $\frac{1}{4}\lambda$. Effective height is a misleading term for loaded aerials—effective current is more definite. This would mean the average value of the current in the vertical part of the aerial, and metre-amperes would be found by multiplying the actual height of the vertical part by the average current in that part. The authors feel that effective height is best expressed therefore as $h_1 = E\lambda d/(377I)$ (I being the maximum current in the aerial, d the distance at which the field strength is measured, and λ the wavelength), whatever the form of aerial. Effective height taken in this way depends upon the distance d. This distance must be chosen so that the field strength at that distance does not suffer attenuation. In practice this distance is safely taken as 5 wavelengths.

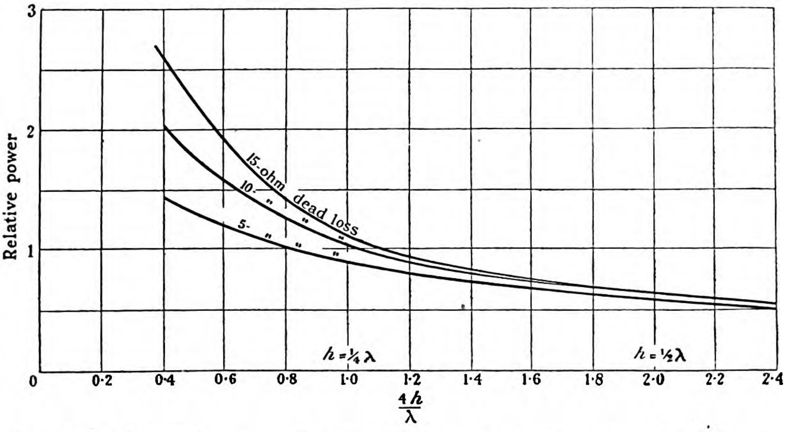


Fig. 5.—*Relative power required to produce a given value of metre-amperes.*

Experimental Tests.—The theoretical analysis was tested by full-scale experiments with a kite balloon supporting various lengths of aerial. The experiments were conducted near Amesbury on Salisbury Plain.

The first experiment was to determine whether, for the production of a given field strength, the necessary power in the aerial was decreased, as theory indicated, by changing from a $\frac{1}{4}\lambda$ to a $\frac{1}{2}\lambda$ vertical aerial. The power in the aerial was measured, and the received field strength was taken as the average of 6 measurements at different points on a circle around the aerial, each reading being taken at 2 km. from the transmitter. Results are shown in table below.

The results as regards effective height are presumably due to earth resistivity, and show that effective height should always be measured rather than assumed. In fact, the choice of a site for a transmitter might well be determined, *inter alia*, by the measure of the effective height of aerials upon it. (The effective height of an aerial at Brookmans Park, near London, used for the attenuation experiments, was the same both by measurement and theory.)

Type of Aerial, h/λ.	Power in Aerial.	Field strength, E, at 2 km.	Effective height (practical), $h_1 = \frac{E\lambda d}{377I}$	Effective height (theoretical), $h_1 = \frac{2}{\pi}h$	Metre-ampere efficiency, $\frac{h_1^2}{\lambda^2}R_T$, where $h_1 = \frac{E\lambda d}{377I}$	Relative watts in aerial to produce given field strength.		Relative field strength at same distance with equal power.	
						Practical.	Theoretical.	Practical.	Theoretical.
	watts	mV/metre	metres	metres		watts	watts	mV/metre	mV/metre
$\frac{1}{4}$	281	64	38	43.5	4.17×10^{-4}	1,000	1,000	1	1
$\frac{1}{2}$	506	109	79.5	87.0	6.66×10^{-4}	625	610	1.26	1.28

It is to be noted that the measured effective

C

height of the $\frac{1}{2}\lambda$ aerial is practically twice that of the $\frac{1}{4}\lambda$ aerial, while measurements have been checked in all ways and there is no doubt as to their accuracy. The results show a substantial gain by the use of the $\frac{1}{2}\lambda$ aerial.

Tests with Franklin Aerials.—Franklin has used, on short waves, as many as three $\frac{1}{2}\lambda$ aerials, one above the other, with a "phrasing-coil" as already shown in Fig. 4. In effect he "wraps up" a $\frac{1}{2}\lambda$ aerial in such a way that it will have the "surge impedance" of a wire $\frac{1}{2}\lambda$ in length but will not produce radiation. The authors tried to produce this effect at frequencies of the order of 1/10th of those used in the beam system, but their efforts were unsuccessful. Fig. 10 shows methods tried or proposed. System (*a*) had been used on 20,000 kc. with complete success, the bifilar phasing device being pulled out at right angles to the aerial. This was impossible, however, on the dimensions necessary for a 300 m. wavelength and with a kite balloon support. The methods are to be tried again on some future occasion, probably using masts for aerial support.

Experimental Fading Tests.—On account of bad weather there was only one fading test. This was to compare fading from a vertical $\frac{1}{2}\lambda$ aerial with that from a T aerial supported by 70ft. masts. The T aerial had a natural wavelength of 288.5 m. (the wave-length used) and was loaded with inductance. The power in the two aerials was not measured.

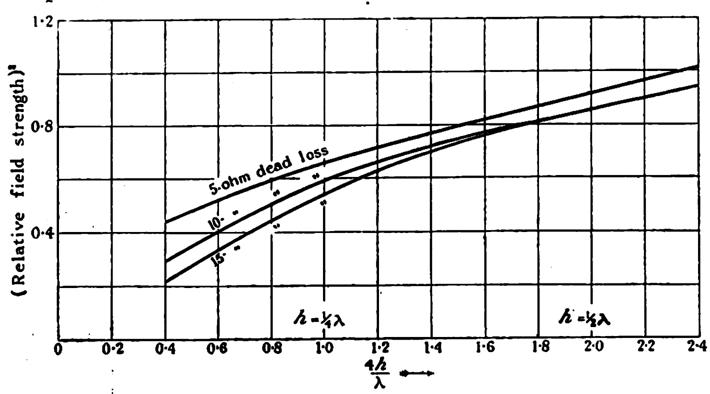


Fig. 6.—*Relative field strength for a given power for various values of h/λ.*

The metre-amperes were, however, measured and the ratio was approximately 2 : 1 in favour of the $\frac{1}{2}\lambda$ aerial, for the same total power input to the transmitter.

There was no fading at 50 miles. At 65 miles the $\frac{1}{2}\lambda$ aerial gave from 20 to 25 per cent. fading while the 70ft. aerial gave a 30 to 40 per cent. fading variation. At 75–80 miles the fading was more pronounced with the low aerial but at 100 miles there was little difference in signal strength on the two aerials, and the fading was less (but not pronouncedly so) with the $\frac{1}{2}\lambda$ aerial.

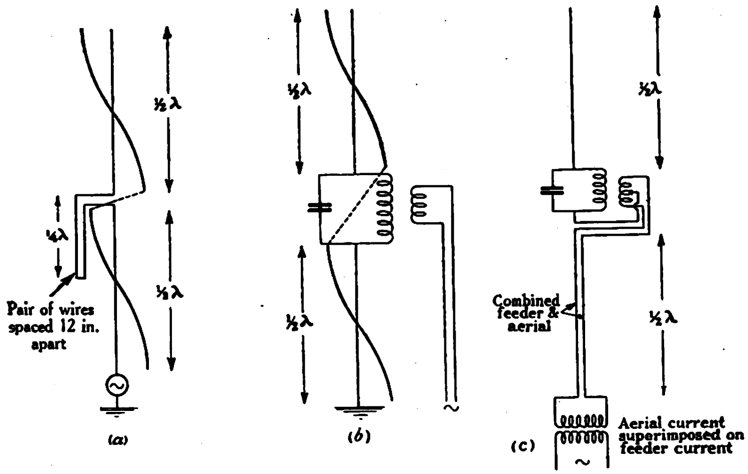


Fig. 10.—*Types of circuit. Circuit (b) is the most promising.*

It appears that at close ranges the ratio of down-coming direct ray was twice as great with the 70ft. aerial as with the $\frac{1}{2}\lambda$ aerial.

There is very little evidence to go upon, but one might generalise by saying that it appears as though the upward radiation was for a given power appreciably the same for both aerials, but, as has been proved by other experiments, the stronger direct ray (for a given power) made a less apparent fading. It would be wrong to place too much reliance upon the results of one experiment undertaken in somewhat trying conditions, but further experiments will be undertaken in the future using high masts. This will allow a more leisurely investigation of the whole problems of fading influenced by the aerial design.

Practical points arising from the results. — The outstanding fact is that high aerials appear necessary, involving high masts and high costs. For the broadcast band of 550 to 200 m. (1,800 to 650ft.) masts for $\frac{1}{2}\lambda$ aerials would have to be of about 1,000 to 400 ft. For two $\frac{1}{2}\lambda$ aerials masts of 2,000 to 750ft. would be required. Mechanical and economic conditions impose a limit of about 800ft., so that Franklin aerials cannot be used for more than 213m., but $\frac{1}{2}\lambda$ aerials can be used on most wavelengths.

A compromise may be looked for in the T aerial, and it would appear best to arrange a T aerial so that the current in the vertical part is a maximum at the greatest possible height from the earth.

It is insisted by the authors that the higher the masts, the greater is the metre-ampere efficiency.

The possibility of using the masts themselves as aerials is discussed, but the authors conclude that the method is not to be recommended, chiefly on account of the lack of flexibility.

If dual masts carrying the conventional type of aerial are to be used, it is particularly important to guarantee that they will not cast shadows of a serious nature. This trouble has been acute at the Daventry broadcasting station and a repetition of the difficulties would be foolish. It is therefore imperative to insulate the mast. It is suggested that the masts could be tuned to have a natural wavelength, when unearthed, equal to the wavelength used, so that no current would flow in the mast when earthed.

Section 2.—Attenuation of Waves.

Sommerfeld's formula for attenuation shows that for a given value of metre-amperes, the field strength is a function of distance x, wavelength λ, the earth's conductivity σ, and its inductivity ϵ, the latter being unimportant except on the very short waves of 10 to 20m. Sommerfeld shows that the signal intensity is only a function of the quantity d_n, which he calls the "numerical distance" and

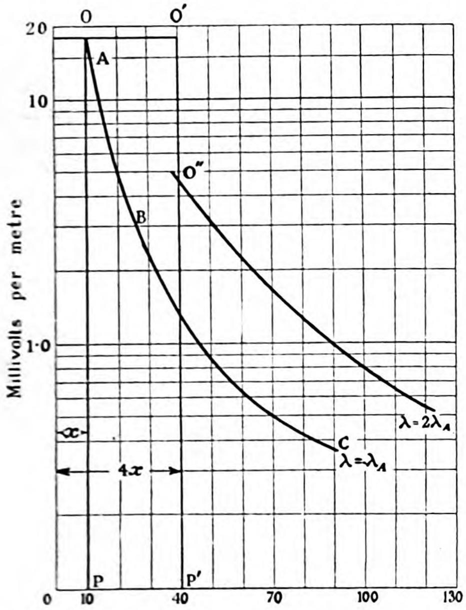


Fig. 11.

which involves the above quantities in the following way :—

$$d_n = \frac{\pi x}{\lambda} \cdot \frac{1}{2\sigma\lambda c} \text{ very nearly,}$$

i.e., within about $\frac{1}{2}$ per cent. on the broadcast band of wavelengths [for σ of the order $\frac{1}{3} \times 10^{-12}$ (electro-magnetic units)]. c is the velocity of light.

The authors then proceed to derive an expression for field strength from the above, reaching the value

$$E = A_1 \left(\frac{h_1 I}{\lambda}\right) \frac{1}{\lambda^2} F_1 \left(\frac{x}{\lambda^2}\right) \quad .. \quad (1)$$

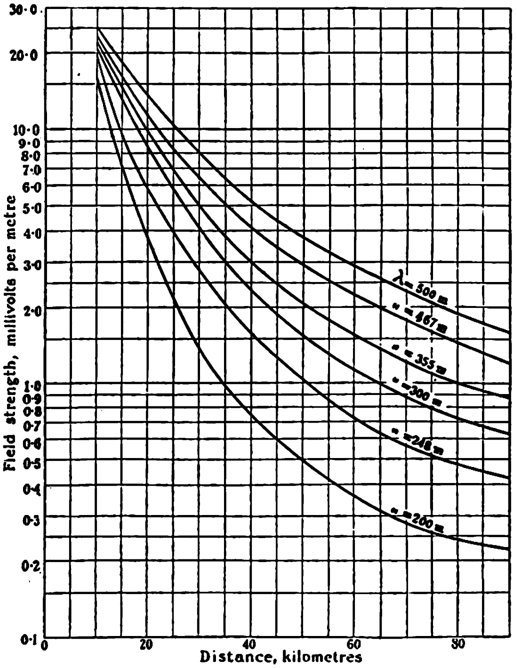


Fig. 12.—*Mean attenuation curves of the northerly and westerly directions.*

The quantity $h_1 I/\lambda$, mentioned previously in the paper, is the similarity factor for all aerials, and expresses the metre-amperes. It gives the initial power radiated and is the multiplier for all attenuation formulæ.

From this it is possible to derive the attenuation curve for any wavelength if that for one wavelength is known. It is only necessary to determine an irreproachable curve for one wavelength or to test the uniformity of the district on two fairly widely separated wavelengths. If such a curve for one wavelength λ_A is plotted others can be derived as follows :—

Let ABC (Fig. 11) be a curve for $\lambda = \lambda_A$, then the curve for $\lambda = 2\lambda_A$, for example, can be constructed as follows :—Let O be a point on the curve ABC for a distance x ; then transfer O to O' at a distance $(4x)$ and reduce O' to O'', where $P'O'' = \frac{1}{4} P'O'$, then O'' will be a point on the curve for $\lambda = 2\lambda_A$. In this way, by choosing a series of points O on the original curve ABC we get a series of points O'' on the curve for $\lambda = 2\lambda_A$. These two curves will give the field strengths for two "similar" stations of λ_A and $2\lambda_A$ respectively.

Barfield has argued* that there may be an extra

* *J.I.E.E.*, 1928, Vol. 66, p. 204, also *E.W. & W.E.*, January 1928.

loss due to trees and vegetation. The authors consider that the only quantity that matters is effective earth resistivity which includes vegetation loss. To take account of changes in the earth's conductivity, E can be written in the form

$$E = \frac{A_2}{x} F_2(d_n) = \frac{A_2}{x} F_2\left(\frac{x}{\sigma\lambda^2 c}\right)$$

where $A \propto h_1 I/\lambda$.

If the conductivity be increased n^2-fold and the wavelength reduced $1/n$-fold, keeping A_1 and x constant, the field strength remains unaltered.

In practice it would be usual to make a measurement of the signal strength in a proposed district, from a transmitter of a known value of metre-amperes on a given wave-length.

If the conductivity in this district is different from the normal it will not lie on the normal curve for λ_1; but will lie, say, on a different curve for, say, λ_2. Then if all the wavelengths on the normal set of curves are altered in the ratio λ_2/λ_1 this new set of curves will represent the complete data for the district.

Experimental Tests.—The B.B.C. made experiments to attempt to get attenuation curves in a given region for all frequencies between 500 and 1,500 kc. The site was near Potters Bar, the aerial consisting of 95ft. of vertical wire, on masts 110ft. high and 300ft. apart, with their bases and stays insulated from earth. Tests showed that the radiation was equal in all directions. The current in the aerial was adjusted so that the field strength at the same point close to the aerial was the same for all the frequencies employed. This meant that $h_1 I/\lambda$ was the same for every wavelength, so that the curves were for the same radiated power on all waves. Curves are given in Fig. 12.

An example is also given of the applications of the method, already outlined, for transferring the curves from one wavelength to another.

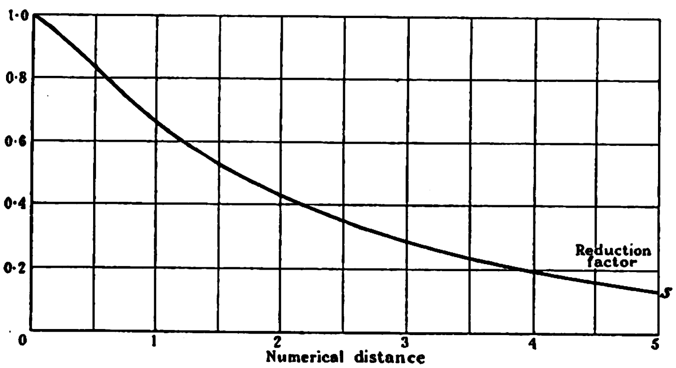


Fig. 14.—*Sommerfeld's theory.*

The authors then discuss the transference of curves for different values of σ. Two transmitters having the same value of $h_1 I/\lambda$ can be said to be similar, whence

$$\frac{377\, h_1 I}{\lambda} = B \text{ (a constant)} \quad .. \quad .. \quad (2)$$

Therefore $E = (B/x)S$, where x is distance. If there were no losses due to the earth and houses, trees, etc., on its surface, the field strength would be $E_0 = B/x$, so that S can be called the reduction factor, and is a function of Sommerfeld's numerical distance, its value being shown in Fig. 14.

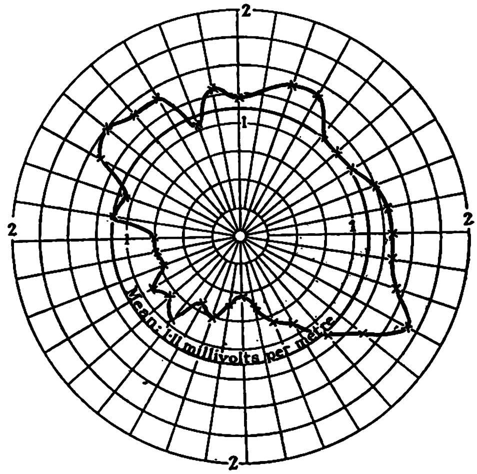


Fig. 15.—*Brookman's Park site. Field-strength map at 40 miles with 10 amperes in the aerial, 388 metres, 780 kilocycles per sec., and 60-ft. masts.*

From Fig. 12 with $x = 60$ km., $\lambda = 248$ m., $E = 0.63$ mV/m. Since these curves are for a radiated power of 1 kW., E_0, the field strength apart from attenuation, will be given as

$$E_0 = \frac{377\sqrt{\left(\frac{1000}{1580}\right)}}{x} = 5 \text{ mV/metre}$$

therefore $S = E/E_0 = 0.126$.

From Fig. 14, $d_n = 5.2 = \dfrac{\pi x}{2\pi^2 \sigma c}$

therefore $\sigma = 10^{-13}$

with $x = 60$ km. and $\lambda = 503$ m., $E = 3$ mV/metre and $S = 0.6$.

From Fig. 14, $d_n = 1.22$, and $\sigma = 10^{-13}$.

The value of σ is thus 10^{-13}, and lies between the wide limits of 0.66 to 5×10^{-13} as given by other observers and found by different methods. It is suggested that it is premature to assume that the total value of σ can be sub-divided into earth loss and vegetation loss. Generally it seems unnecessary to assume that there is any loss over and above the earth loss, except where the waves traverse large cities or heavily wooded country. More "irreproachable" curves must be taken before this can be accurately determined.

Fig. 15 gives a polar diagram for an aerial, the initial radiation from which was strictly sym-

metrical in all directions. Middlesex lay on the south side, which explains the large degree of concavity of the base of the Figure.

Conclusion.

The facts which emerge from the paper are

(1) Aerials for broadcasting should produce the strongest possible horizontal radiation, while diminishing upward radiation.

(2) To do so, high aerials are essential.

(3) Special aerial design will not prevent a serious limitation of service area with short waves, relative to that obtained with longer waves.

(4) That organisations must nevertheless employ such waves, which are more efficiently used with high aerials.

The curves of Fig. 17 show theoretical field strength for a vertical aerial 400ft. high, while Fig. 18 shows the improvement of increasing the aerial to 700 ft.

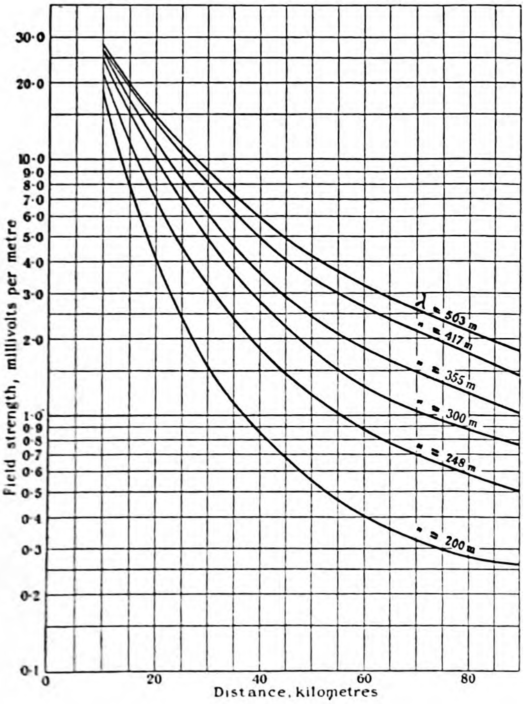


Fig. 17.—*Theoretical field-strength curves for various wavelengths using a vertical aerial 400 ft. high (500 ft. masts) having a constant dead loss of 10 ohms. All curves for 1 kW. input to aerial.*

It is also shown that interference—natural and artificial—diminishes with wavelength, and the authors take this factor of diminution as being proportional to the square of the frequency. This still further improves the curves of Fig. 18, so that if, with ¼λ aerials, say 25 kW. are required for a given service, with 700ft. aerials this can be done with 10 kW.

It is thus suggested that the broadcast engineer need not so greatly fear to use waves below 300 m., the use of which must come, while it is hoped that the paper may be of help to those who will one day have to use them.

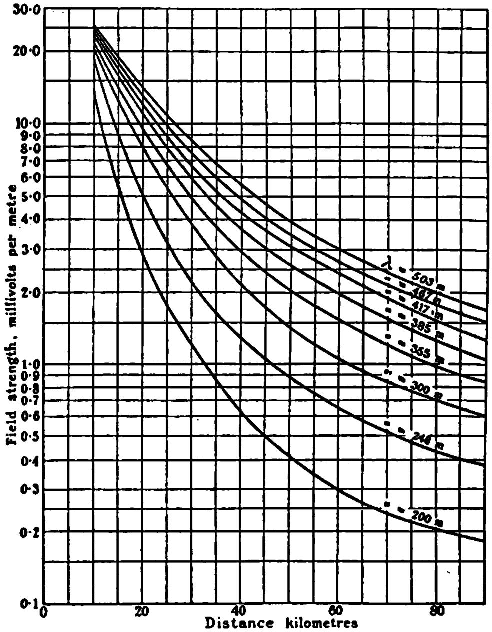


Fig. 18.—*Theoretical field-strength curves for various wavelengths using a vertical aerial 700 ft. high (800 ft. masts) having a constant dead loss of 10 ohms. All curves for 1 kW. input to aerial.*

Discussion.

The discussion which followed the reading of the paper was opened by *Dr. R. L. Smith Rose*, who expressed his appreciation of the paper and of its presentation. The authors followed the perceptible trend to use the direct wave. The resistance of the ground as a factor of attenuation had been neglected for 20 years and it was not until broadcasting that attention had been paid to ground attenuation.

In connection with the upward radiation, he quoted the case of an aerial at Teddington, practically entirely vertical, from which little radiation upwards would be expected. Nevertheless at such short distance as King's College waves had been detected which had been up to two layers and were arriving at 1 deg. to 4 deg. from vertical and of strength comparable to the direct ray.

The author's method of deriving a family of attenuation was interesting, but there was difficulty in getting an "irreproachable" attenuation curve as suggested. The country was nowhere uniformly flat. He did not see that any new knowledge had been brought out. Mr. Barfield had already dealt with attenuation in great detail and he thought that this work might have been used by the B.B.C.

The curves given were not superior to those already in existence.

Mr. R. M. Wilmotte discussed the subject of effective height and referred to the difficulties of measuring this even at 5 wavelengths distance. Ratcliffe and Barnett had found an increase at short distances, and it was necessary to find reasons for such effects. The author's suggestion of the use of " effective current " did not meet the case as this was not a property of the aerial, but of other factors. Such a value as " radiation factor " might be more useful. In his own work on aerials he had used a " directive efficiency " which was the ratio of radiation in space to that in a given direction. He had recently calculated the effect of an increase in the top of a T aerial and results obtained by Messrs. Barfield and Munro had shown very good agreement with the increase calculated from theory. He suggested that more information on the methods of measurement used in the experimental work described would be desirable.

Mr. R. H. Barfield said that his chief interest in the paper was in the section on attenuation. His own work gave results in different directions on one wave; the present paper gave results on different waves. Where they overlapped they agreed. He quoted from an earlier paper* of his own on the subject of earth conductivity and the effect of trees. The actual conductivity over regions does not vary within wide limits. He had recently made experiments on the seasonal change of absorption due to trees and had found as much as 30 per cent. as between winter and summer. Observations on Bournemouth over all the year also showed a seasonal effect. The value of the curves given by the authors was limited without a knowledge of the conductivity of the earth involved.

Mr. E. H. Shaughnessy spoke briefly of the author's work and of the importance of aerial design as a factor of economy.

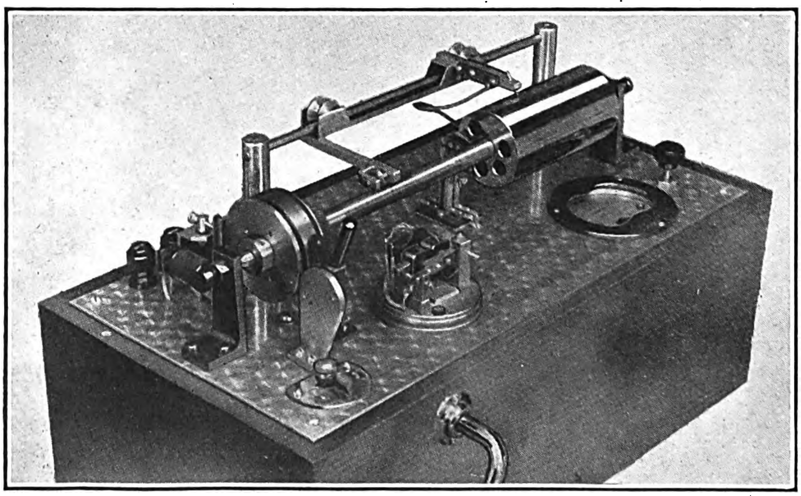
Mr. F. H. Amis thought that foreign broadcasting authorities realised the need for good service. Much of the interference experienced was accidental and could possibly be improved by representation to the authority concerned. A great need was for several stations to work on one wavelength without interference. As regards the lessening of fading from higher aerials, he quoted the considerable fading noticed from Germany—the home of the high aerial. In experiments in Sweden on 260 m. a half wavelength T aerial had shown 25 per cent. improvement over a quarter wavelength vertical, while a half wavelength vertical had shown 80 per cent. improvement. Other comparisons of improvements effected in some European stations were also quoted. It was necessary to keep the maximum current away from absorbing masses. This meant that the point of maximum current must be raised farther up the aerial.

Lt.-Col. A. G. Lee did not think that the authors had found a cure for fading. He did not consider the improvements shown by the authors were worth the cost. While they had made a case for higher aerials, they had not worked out the relative costs. Why not use more power in a quarter wavelength aerial? He also asked had the authors considered the use of horizontally polarised waves? This should be possible without any cost of masts.

Capt. P. P. Eckersley briefly replied to the discussion. He said they had not reached the stage of irreproachable curves, but that every care was taken in the measurements. For effective height six points were taken. In the matter of the effect of trees, they were not in conflict with Mr. Barfield, but he thought it was difficult to apply this effect in practice. High aerials did not show as much amelioration of fading as was expected, but might lead to the use of less power. Consideration of cost still showed in favour of higher masts and less power.

On the motion of the Chairman (Commander J. A. Slee, C.B.E.), the authors were cordially thanked for their paper.

* *Loc. cit.*



Facsimile Picture Reception.

A rapidly growing interest in broadcast picture reception is giving rise to the development of designs for apparatus suitable for amateur and home use. This machine, for home assembly, which conforms to the conditions of the 5XX picture broadcasts, as well as those from German and Austrian stations, has been the subject of recent articles in *The Wireless World*. Synchronisation is effected by the transmission of a brief signal once each revolution, for which purpose a relay, magnetic clutch and catch and switching cams are provided, the necessary valve rectifier being on the underside of the panel.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Effect of Anode-grid Capacity in Detectors and L.F. Amplifiers.

To the Editor, E.W. & W.E.

SIR,—In his article on the above subject Mr, Medlam claims to show that the feed-back due to the anode-grid capacity of a valve operating as an anode-band detector produces quite a considerable amount of distortion—in fact, such an extraordinarily large amount as to call for a very careful examination of the analysis by which Mr. Medlam is led to this conclusion. Such examination, I think, reveals that some of the mathematical work is open to very considerable criticism. The two points in the purely mathematical development to which I would draw attention are the equations

$$\frac{dv}{dt} = \frac{i_g}{C_{ga}} + L_e\frac{d^2i_g}{dt^2} \quad \ldots \quad \ldots \quad (12)$$

and

$$e_r = \omega L_e i_g \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

L_e denotes what Mr. Medlam terms the "equivalent inductance" of the input circuit and the above equation (12) is clearly derived on the basis that the voltage drop across this equivalent inductance, due to the current i_g fed back through the anode-grid capacity, is equal to $L_e\frac{di_g}{dt}$. Although it is only intended to use the steady state solution of the differential equation subsequently derived, the above equation can only legitimately be used if the resistance of the input circuit can be neglected. This limitation is not mentioned at this stage of the work, though it is subsequently shown that under the particular conditions of tuning assumed by Mr. Medlam the resistance terms in the expression derived for this equivalent inductance are relatively negligible (*see* (24)).

But how, then, can we reconcile equation (14)? e_r denotes the feed-back voltage, and this is precisely the potential drop across the equivalent inductance which has been taken in equation (12) as equal to $L_e\frac{di_g}{dt}$. But equation (14) states that this potential drop is equal to $\omega L_e i_g$. Since we are dealing with the instantaneous values of e_r and i_g, $\omega L_e i_g$ is not at all the same thing as $L_e\frac{di_g}{dt}$. As a relation between *instantaneous* values the equation $e_r = \omega L_e i_g$ can only mean that e_r is in phase with i_g, whereas $L_e\frac{di_g}{dt}$ represents a voltage 90 deg. out of phase with i_g. While, therefore, the use of the expression $L_e\frac{di_g}{dt}$ to represent the voltage drop across the equivalent inductance is open to criticism, the statement $e_r = \omega L_e i_g$ appears to me to be quite indefensible, and any conclusions derived from an analysis making use of this relation cannot be expected to be valid.

Quite apart, however, from the soundness, or otherwise, of the mathematical work, there is another point to which, I think, exception must be taken. If I understand rightly, Mr. Medlam assumes the input circuit to be so tuned as to apply a maximum potential difference between grid and filament when the latter is disconnected from its supply, and the circuit is not supposed to be re-tuned to allow for the de-tuning effect of the feed-back when the valve is working. If this is so, it would not be at all surprising if a correct analysis were to show that distortion does occur in such circumstances. Surely it is well known that a slightly de-tuned circuit does cause a certain amount of distortion! Again, it appears to me that to obtain a true estimate of the amount of distortion produced, it is not sufficient to consider merely the distortion which may be produced in the grid-filament potential difference, but it is necessary to examine what is the amount of consequent distortion of the wave-form of the rectified current in the anode circuit. This would appear to be the only true criterion of the distortion produced. While it is quite certain that distortion of the potential difference to the extent indicated by the curves in Figs. 7 and 9 would result in considerable distortion of the current wave-form, it is by no means certain that it would be comparable with that present in the potential difference, and it is quite possible for a certain relatively small amount of distortion of the potential difference to occur without its being reproduced in the current wave-form to any appreciable extent at all.

A further point which strikes one in Mr. Medlam's results is the enormous reduction in the carrier-wave component of the grid-filament potential difference which is indicated by Fig. 4, particularly in view of the small values of amplification factor to which the curve applies. Since, by (37), the ratio $\frac{cE_g}{E}$ varies nearly inversely as μ, consider what an enormous reduction of potential difference is indicated in the case of a valve working as a grid-leak detector with a value of μ of anything from 10 to 20! This result in itself appears to me to be sufficient to throw considerable doubt on the validity of Mr. Medlam's conclusions.

Since reading his article I have examined the question somewhat carefully, taking account even of terms of the order $\frac{m^2}{\omega_c^2}$ compared with unity, and the conclusions I have reached are the exact opposite of those derived by Mr. Medlam.

According to my analysis, *provided the input circuit is properly re-tuned to allow for the de-tuning effect of the feed-back*, the distortion produced in the grid-filament potential difference by the feed-back—both as regards magnitude and phase—is only of the order $\frac{m}{\omega_c}$ compared with unity, and the resulting distortion of the rectified current of

modulation frequency is only of the order $\frac{m^2}{\omega_r^2}$ compared with unity.

The sole appreciable effect of the feed-back is to increase the effective resistance of the input circuit, and this it does only to a far less extent than indicated by Mr. Medlam. In fact, for the example given by him, I find an increase of only 3 per cent. for a value of $\mu = 0.15$, whereas he finds an increase of 100 per cent.!

While I do not expect these conclusions to be taken on trust, I think it must be admitted that there are adequate grounds for not accepting Mr. Medlam's results without further examination.

E. A. BIEDERMANN.

Brighton.
25th October, 1928.

To the Editor, E.W. & W.E.

SIR,—Mr. Biedermann's letter contains a whole series of unfortunate assumptions. The first of these occurs in the latter part of his opening sentence. Mr. Biedermann assumes that I was led to the conclusion stated as the result of a mathematical analysis. As a matter of fact I first became aware of the distortion experimentally some twelve months ago. In a certain test a surprising amount of distortion occurred. Its origin was investigated and traced experimentally to feed-back. Some time afterwards it occurred to me to attempt a mathematical analysis to see if the observed effects could be accounted for on theoretical grounds. The resulting analysis gave such a reasonably close quantitative agreement with the experimental observations, on the carrier and outer side-bands, that I had no hesitation in assuming the substantial accuracy of the results of the analysis.

The first point of Mr. Biedermann's criticism is on the omission of resistance terms from the equations. This omission was deliberate, and was made with full knowledge of its implications. A complete and exact solution of the problem, applicable to all cases, is so complex as to be of no practical value. Thus one is forced to narrow the scope of the solution, by assuming this and that, until a manageable result emerges. In the present case, even if the resistance terms had been of considerably more importance than they really are, I should probably have restricted the scope of the solution still further rather than include them; provided, of course, that the order of the results still agreed with experimental observations.

I agree with Mr. Biedermann's comment on equation (14). There is an obvious slip here. This equation, for the case considered, should read $e_r = L_o \frac{di_g}{dt}$. This change slightly alters the form of the solution, but has little effect on the numerical values of e_g on the carrier and outer side-bands. The phase shifts of the side-bands, however, are modified considerably, particularly as there is a misprint in the original equation! The corrected solution (equation 18) should read

$$e_g = E\sqrt{\frac{k_1^2 + k_2^2}{(k_1 - \mu)^2 + k_2^2}} \sin\left[\omega t + \tan^{-1}\frac{k_2}{k_1} - \tan^{-1}\frac{k_2}{k_1 - \mu}\right],$$

in which k_1 has its original value, and k_2 (equation 20) has a + instead of a − sign between the terms in the brackets. Equations (26) and (27) may be taken to be unaltered. The denominators in (34), (35) and (36) should be corrected to the form $(k_1 - \mu)^2 + k_2^2$, and (37) should read

$$cE_q = .091E/(.091 + \mu).$$

The only other change is in (38), in the numerator of which μ should replace μ^2, while the denominator should read $(k_1 - \mu)^2 + k_2^2$.

The tuning condition given in my article was assumed only after due consideration. The exact condition could be obtained only by differentiating for a maximum value of e_g a complete solution for the untuned case. This solution, including resistance terms, involves a differential equation of the fifth order, the coefficients of which involve, literally, thousands of terms. For example, the coefficient of $\frac{d^4e_g}{dt^4}$ has 2416 terms! In view of the complex nature of the exact solution I did not present this in the article, but finally adopted the much simpler tuning condition given. The difference between the two conditions is minute; and besides, it was known from experimental results, obtained under average conditions, that re-tuning to allow for feed-back has no appreciable effect.

The question of distortion of the L.F. current wave form in the anode circuit is outside bounds. I am not sure that I agree with the last part of the paragraph in Mr. Biedermann's letter dealing with this point—but it would take too long to explain.

Regarding the enormous reduction in the carrier wave component when μ has its normal value, this effect has been experimentally verified for a valve adjusted for amplifying conditions. Although I did not personally carry out the experiments on this point, I have seen results showing the input voltage reduced by feed-back to some 5 or 10 per cent. of its original value. That my theoretical results show a large reduction does not at all "throw considerable doubt on the validity" of my conclusions: *it proves them.*

In view of the above it is unnecessary for me to comment on the theoretical results Mr. Biedermann claims to have obtained. On this matter I will take up only the statement to the effect that the rectified current of modulation frequency is proportional to the square of the input modulation voltage. This is not at all the case if an anode bend detector is used under proper operating conditions. It has been shown theoretically by Colebrook, and experimentally in the paper referred to in my article that the relation between the anode current of modulation frequency and the input voltage modulation depth is practically linear if the mean carrier input is of the order of 1 volt. The square law does not operate until the mean input drops to about 0.25 volt—and this type of detector would not be used, normally, on such small inputs for other reasons.

Regarding the last sentence in Mr. Biedermann's letter, I hope that, after reading my reply, he will come to the conclusion that my results are better grounded than he imagined.

In conclusion, I may add that since reading Mr. Biedermann's letter I have made some measurements on modern types of valves. A PM4DX valve with a capacity of 50 $\mu\mu$F. across the external anode resistance showed a drop in input voltage due to anode-grid capacity somewhat exceeding 50 per cent. on the carrier frequency (10^6 cycles), with little disturbance of the original input on the side-bands corresponding to the higher audio frequencies. Also, a Pentode tested under the same conditions failed to show this effect—the change in input voltage due to anode-grid capacity was in this case very slight, both on the carrier and all side-band frequencies.

WM. B. MEDLAM.

The Problem of International Distribution of Broadcast Wavelengths.

To the Editor, E.W. & W.E.

SIR,—I beg to advise you that a mistake has occurred in Table I, where in 21/Poland, column 8, the figure 8,33 should appear in place of 6,33. The total will, however, remain unchanged.

W. S. HELLER.

The Transmitting Station actually sends out Waves of One Definite Frequency, but of Varying Amplitude.

To the Editor, E.W. & W.E.

SIR,—The recent correspondence on the above subject has presented several features of considerable interest. The question raised by your correspondent, Mr. Frank Aughtie, whose letter was published in your December issue, falls into this category.

It must be admitted that it is at first sight difficult to form a clear mental picture, from the purely physical standpoint, of the reason why, if we listen to the second harmonic of a modulated radio-frequency wave, we do not observe all the tones of the modulation to have been raised in pitch by one octave. A simple mathematical analysis, however, renders the matter perfectly clear.

Let us assume that we have a carrier whose instantaneous value, unmodulated, may be represented by $i = i \,.\, \sin \omega t$. Then, if we assume this to be modulated by a sine wave of frequency $\phi/2\pi$, to a degree a, the complete expression for its instantaneous value is known to be

$$i = i \,.\, \sin \omega t(1 + a \cos \phi t) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$= i \,.\, \sin \omega t + ai \,.\, \sin \omega t \,.\, \cos \phi t.$$

$$= i \,.\, \sin \omega t + \tfrac{1}{2} ai \,[\sin (\omega + \phi)t + \sin (\omega - \phi)t]$$

$$= i \,[\sin \omega t + \frac{a}{2} \sin (\omega + \phi)t + \frac{a}{2} \sin (\omega - \phi)t] \quad (2)$$

The above is, of course, perfectly well known, and shows why it is necessary to regard a carrier modulated with a sine wave as being identical in all respects as the same carrier plus two side bands, all of constant amplitude. It is to be noted that the two expressions, (1) and (2), are mathematical identities, no mysterious processes, valve rectification, etc., are involved in the production of one from the other.

If now we take such a modulated wave, and apply it to the grid of, say, an amplifying valve, which is not working in a linear manner, harmonics will be present in the radio-frequency output of the device. Now a dynamic valve characteristic is very nearly parabolic in form, and may therefore be represented mathematically in the form

$$Y = AX^2 + BX + C \quad \ldots \quad \ldots \quad (3)$$

where A, B and C are suitably chosen constants, and where X, which may be any function we please, represents the input to the valve, Y representing the corresponding output.

In order to see what will be the terms present in the output of the amplifier which we have imagined, we have plainly to substitute for X in equation (3), X being of the form of either (1) or (2).

Now the term in (3), which is instrumental in producing harmonics, is that involving X^2; in other words, all we have to do in order to find the relation between the various harmonics produced by such a valve is to square either (1) or (2), and examine the terms contained in the result. Plainly it will not matter which form of the function we employ.

From (1):

$$\bar{i}^2 = i^2 \sin^2 \omega t(1 + a \cos \phi t)^2.$$

$$= i^2 [\sin^2 \omega t + 2a \sin^2 \omega t \,.\, \cos \phi t + a^2 \sin^2 \omega t \,.\, \cos^2 \phi t].$$

$$= i^2[(1 - \cos 2\omega t)/2 + a(1 - \cos 2\omega t) \cos \phi t + a^2(1 - \cos 2\omega t)(1 + \cos 2\phi t)/4].$$

$$= i^2[\tfrac{1}{2} - (\cos 2\omega t)/2 + a \cos \phi t - a \cos 2\omega t \,.\, \cos \phi t + a^2(1 - \cos 2\omega t + \cos 2\phi t - \cos 2\omega t \,.\, \cos 2\phi t)/4].$$

$$= i^2[\tfrac{1}{2} - (\cos 2\omega t)/2 + a \cos \phi t - \tfrac{1}{2} a \cos (2\omega - \phi)t - \tfrac{1}{2} a \cos (2\omega + \phi)t + a^2/4 - (a^2 \cos 2\omega t)/4 + (a^2 \cos 2\phi t)/4 - a^2/4 \,.\, \tfrac{1}{2} \cos (2\omega - 2\phi)t - a^2/4 \,.\, \tfrac{1}{2} \cos (2\omega + 2\phi)t].$$

$$= i^2[\tfrac{1}{2} + a^2/4 + a \cos \phi t + \frac{a^2}{4} \cos 2\phi t - \tfrac{1}{2} (\cos 2\omega t + a \cos \overline{2\omega - \phi} \,.\, t + a \cos \overline{2\omega + \phi} \,.\, t) - (a^2/4) (\cos 2\omega t + \tfrac{1}{2} \cos \overline{2\omega - 2\phi} \,.\, t + \tfrac{1}{2} \cos \overline{2\omega + 2\phi} \,.\, t)] \quad \ldots \quad \ldots \quad (4)$$

By inspection of expression (4) we see that the radio-frequency harmonics present in the output of the valve consist of (*a*), a carrier of twice the original carrier frequency, together with side-bands corresponding to modulation of the original frequency, and (*b*), a carrier of twice the original frequency, together with side-bands corresponding to twice the original modulation frequency.

It is to be noted further that in the case of (*a*), the percentage modulation is double that of the original modulated carrier, and therefore if the latter was more than 50 per cent. the harmonic will be overmodulated and therefore its envelope will not be sinusoidal.

In the case of (*b*), the magnitude of the whole group of terms is small compared with (*a*) on account of the factor $a^2/4$, a being never greater than unity.

Thus, in practical terms, if we listen to the second harmonic of any modulated carrier we shall hear the original modulation and not the octave, but a certain amount of harmonics of the original modulation frequencies will always be present, introducing more or less distortion. This, of course, is strictly in accordance with practical experience.

As already stated, it is plainly immaterial whether we start with expression (1) or (2), since these are identities. Had we started with expression (2) we should have had to square a function of the form $A + B + C$. The result would have been of the form

$$A^2 + B^2 + C^2 + 2AB + 2BC + 2CD.$$

This would have reduced to expression (4) above. The fallacy in Mr. Aughtie's argument arises from the omission, in effect, of the last three terms, $2AB + 2BC + 2CD$.

The whole matter only confirms that from every point of view all observed facts can be explained by either the side-band or the varying amplitude theory of a modulated carrier.

In this connection it is interesting to consider the effect of a fairly lightly damped tuned circuit, such as an aerial may be, on a modulated carrier. Some of your correspondents seem to have difficulty in visualising the cutting off of the higher modulation frequencies by such a circuit on the basis of the constant frequency—changing amplitude conception, though they readily appreciate the effect of a sharp resonance curve as regards response to side-bands. Surely the explanation is that if a tuned circuit has a sharp resonance curve its decrement is low, and hence it is difficult for any oscillation at the resonant frequency of the circuit to build up and decrease in amplitude sufficiently rapidly to reproduce the higher modulation frequencies.

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Effect of Frequency on the Value of Resistances.

To the Editor, E.W. & W.E.

Sir,—In reply to Mr. Coursey's correspondence on my tests on grid leak resistances, I regret that my description of the Dubilier leaks tested has led to a misunderstanding.

The type of Dubilier leak tested and described as consisting of a strip surrounded by a glass enclosure was one of the earliest of the Dumetohm pattern marketed by the Dubilier company. The misleading description of this leak is the result of an incomplete examination of the metallised filament, which I am now pleased to correct.

The leak described as the "usual type of Dubilier leak" and consisting of a strip of compressed material surrounded by a layer of wax and enclosed in a cylindrical casing of compressed paper, conforms to the old pattern mentioned by Mr. Coursey, a pattern which I was unaware is now obsolete.

I trust that this may remove any possible misunderstanding which my statements have incurred.

W. Jackson.

Burnley.

Alignment Valve Characteristics.

To the Editor, E.W. & W.E.

Sir,—In a recent article your contributor, Mr. Reed, described an alignment chart for the purpose of deriving valve characteristics, and claimed that by means of it any one of the three usual forms of graphical characteristic could be rapidly reproduced. This, of course, is quite correct. May I, however, be allowed to express the opinion that in thus limiting the functions of the alignment chart Mr. Reed is, perhaps unconsciously, passing over the chief merits of a method which deserves to be more widely known.

I would suggest that, in cases where alignment representation is possible (as in this instance by virtue of an assumed formula) it would be better to connect the related variables directly by alignment in a manner analogous to that described in an article which I contributed to your pages in May, 1927. To describe the method would occupy too much space for a letter, but it may be said here that such an empirical chart will be much easier to construct than Mr. Reed's example. But the chief merit of such an inverse chart is that by means of it we can go behind and dispense with the formula, which is, after all, only an approximation. If desired, too, such a chart can be used as a basis from which the constants of the formula themselves may be derived. This is an important feature of the method, and is worth special emphasis.

Mr. Reed says nothing as to the process by which the constants of the Van de Bijl formula were derived. It is only after they are determined that he calls the alignment process into play. Since the whole application of these methods to valve characteristics is admittedly approximate, it seems in every way more desirable that the nature and amount of the approximation should throughout be determined by alignment methods. In other words, an alignment chart constructed directly from the observed data is likely to be more satisfactory than one which is derived at second hand, as it were, through the medium of a particular numerical formula. The extreme flexibility of the alignment process when thus used inversely (*e.g.*, simplicity of arrangement and graduation of scales) has already been mentioned in these pages (*loc. cit.*). On the whole it seems a pity that when dealing with so essentially an experimental subject as valve characteristics, Mr. Reed confined himself solely to the computational uses of alignment, and omitted all reference to its value in the correlation of experimental data.

As an enthusiastic advocate of alignment methods, and a firm believer in their utility in wireless engineering, I do not feel such criticism to be a particularly gracious task. But it is, I hope, constructive, and in the interests of the science Mr. Reed will, I am sure, pardon my impression that it was necessary.

W. A. Barclay.

Arcadia, Bieldside, N.B.

Abstracts and References.

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PROPAGATION OF WAVES.

FELDSTÄRKEMESSUNGEN AUF GROSSE ENTFERNUNGEN IM RUNDFUNKWELLENBEREICH (Field Strength Measurements at great distances for Broadcast Wavelengths).—M. Bäumler. (*E.N.T.*, November, 1928, V.5, pp. 473–477.)

Preliminary results of a quantitative investigation into the propagation of test waves of 190, 405 and 585 m., transmitted in long dashes from Döberitz and measured at five collaborating institutions at distances ranging from 90–545 km. all using the Anders method. Tables and charts are given. The Hertzian values (calculated for propagation in free space) are nearly reached—once, apparently, actually reached— by occasional night peak-values. This was also found by the writer, in 1924, to occur on Rocky Point and Marion wavelengths (16,400 and 11,600 m.). It is supposed that intermediate wavelengths behave similarly. Fading observations are discussed. Some of these, recorded by a semi-automatic procedure, were on 190 m. and showed slow fading periods of 1½ minutes. Possibly these could be attributed to the transmitter. Apart, however, from this particular group, the writer states that the observed strong fadings at night, if caused at all by interference between two waves, could only be caused by interference between two waves of practically equal strength: the surface wave would not be strong enough: two waves by similar but differing paths must be concerned, or else some meteorological cause. The paper deals next with attenuation, giving a table of values for alpha (in the expression $\epsilon^{-\alpha d}$) for the several wavelengths and over the several distances. A comparison with Austin's "over-sea" formula gives an average value for α over land about 10 times as great as over sea—"a relation confirmed by other measurements in the broadcast zone." The paper ends with some atmospheric measurements, chiefly of "grinders" which varied from 1.5 to 6, with an occasional rise to 10 microvolts per metre. On 190 m. wavelength somewhat smaller values were obtained. Occasional strong "clicks" reached 26 $\mu V/m$.

DAS VERHALTEN KURZER WELLEN IN UNMITTELBARER NÄHE DES SENDERS (The Behaviour of Short Waves in the Immediate Neighbourhood of the Transmitter).—J. Fuchs. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 170–171.)

The difference in short wave radio reception by day and night is supposed to be due to the variation in ion concentration in the upper atmosphere. The smallest height for the conducting layer is estimated by Pedersen at 70 km. The writer, since 1926, has observed field strength decreases at night (as great as from $40\mu V/m$ to $3\mu V/m$) on 43 and 30 m. waves at a distance of a mere 10 km., and smaller decreases at distances down to 4 km., on a 20 m. wave. Attempts to reconcile these results with the theory would involve assuming either that the lowest surface of the Heaviside layer was only about 3.5 km. from earth, or that the night ionisation was far greater than it is thought to be — a supposition involving great difficulties in the matter of long distance reception of other short waves. A third explanation—that the ray is inclined at about 88 deg. and at night penetrates the layer and does not return to earth—is untenable because in actual fact the signals at night were excellent behind the skip zone.

SHORT WAVE ECHOES AND THE AURORA BOREALIS.—B. van der Pol. (*Nature*, 8th December, 1928, V. 122, pp. 878–879.)

Facts here mentioned prove the authentic character of the Stôrmer-Hals echoes dealt with in last month's Abstracts. They are difficult to observe, but they have been heard by several observers at different places and sometimes simultaneously. Though their oscillation frequency could easily be identified as the same as that of the original signal, the three dots of the latter could not be recognised in the echo, which was of a blurred nature; except in one case where the echo was 3 seconds after the signal and the three dots were plainly audible.

The writer suggests, as an alternative to Stôrmer's hypothesis that the waves actually penetrate the layer, that the waves may penetrate well into but not through the layer. As Appleton has shown, the layer usually has a relatively well marked lower boundary against which waves travelling nearly vertically are sharply reflected. The apparent dielectric constant diminishes with [an increase of] the density of electrons, and even becomes zero for waves of 31.4 m. length when the density is about 10^6 electrons per c.c. Moreover, since $v_p \times v_g = c^2$, at the places where the electron density is near the critical one the phase velocity becomes infinite—but at the same time the group velocity approaches zero. When it happens that the relative variation of density with height (over a distance of a wavelength) is small, the waves may penetrate and soak well into the layer and travel in regions where v_g is small; they will then be reflected at the region where the apparent dielectric constant approaches zero. Thus any time-interval between signal and echo can be expected to occur, the phenomenon being wholly governed by the gradient of electron density; this fits in with the other echoes found by Taylor and Young, and with the general fact that the time-interval is extremely variable.

Short Wave Echoes and the Aurora Borealis.—E. V. Appleton. (*Nature*, 8th December, 1928, V. 122, p. 879.)

In connection with the Stôrmer-Hals echoes, the writer suggests that such long temporal retardations of short wave signals may be explained by purely terrestrial agencies. At the U.R.S.I. meeting last September, in discussing the first announcement of similar (shorter) retardations (Taylor and Young, Abstracts, 1928, V. 5, p. 460) he pointed out that waves meeting the ionised layer at vertical incidence would travel upwards until they were "reflected" at a point where the group velocity was reduced to zero; and that if the ionisation gradient in this region was not large, the waves might be appreciably retarded before and after reaching the critical value of ionisation. The retardation of any signal sent up from the ground and received there again is $\frac{1}{c}\int\frac{ds}{\mu}$ (where c is velocity of radiation *in vacuo*, ds an element of path, and μ the refractive index), and this quantity may greatly exceed $\frac{1}{c}\int ds$ if μ is very small for an appreciable part of the path. He mentions here that Borrow, in London, has obtained photographic registration of echoes from Eindhoven corresponding to retardations of 1 second—intermediate between the Taylor-Young and Stôrmer-Hals retardations. As possible paths in which the waves could remain travelling with a low group velocity in the ionised layer for so long as 10 seconds and yet reach the ground again with appreciable intensity, he suggests voyages round the earth or horizontal journeys into the sunset (or sunrise) discontinuity in the layer, with reflection there (*cf.*, Hoag and Andrew, January Abstracts). If the group velocity is small the signal intensity is reduced to $\epsilon^{-ft/2}$ of its initial value, f being the frequency of electron collisions with air molecules and t the time of retardation in the layer. If the commonly accepted values for f are correct, the attenuation of signals retarded by travelling at heights up to 400 km. would be very great. But if there were sufficient ionisation at heights of 600 km. or more, retardation without much absorption could take place. The writer suggests another possibility—that if the ionised layer is regarded as a reflecting shell, there will be convergence of transmitted waves to some point near the Antipodes which—in turn—may be regarded as a source whence another set of waves emerges. Conditions in the layer alter very rapidly, so that the points to which the waves converge every 1/7 sec. (the time of a circumferential journey) will vary rapidly. It thus may be some seconds before a particularly loud repetition reaches a particular region of the earth. He concludes by foreshadowing some tests on 30 m. waves to determine whether they do or do not penetrate the layer when they meet it at approximately vertical incidence.

The Attenuation of Wireless Waves over Towns.—R. H. Barfield and G. H. Munro. (*E.W. & W.E.*, January, 1928, V. 6, pp. 31–37.)

Full abstract of the paper read before the Wireless Section of the I.E.E. on 5th December, 1928, and of the subsequent discussion. It is divided into three parts: Description of Experimental Work (measurement of the polar curve of 2LO and construction of a revised contour map; experiments to determine change of attenuation with wavelength); Theoretical Discussion of Results; and Conclusion. There is an Appendix, Experimental Confirmation on Short Wavelengths.

Radio Transmission and the Upper Atmosphere.—G.W.O.H. (*E.W. & W.E.*, December, 1928, V. 5, pp. 657–659.)

An editorial on the results of Appleton's investigation as to the concordance which might be expected between the three main methods of determining the effective height of the Heaviside layer: namely, the wavelength change, angle of incidence, and group-retardation methods. If the atmospheric ray travelled with a constant velocity until it met the lower surface of an ionised layer and were there reflected in the ordinary way, all three methods would necessarily give the same result for the height of that lower surface, unless the reflection introduced a change of phase which varied with the wavelength. If, however, the ray enters the ionised layer and, owing to the increasing ionisation and consequent increasing velocity with increased height, is refracted along a curved path back to the surface, through it, and down to earth, it is by no means evident that the three methods should give the same result; in fact, at first sight, it looks rather improbable. But the complete theoretical investigation shows that even here the three methods should lead to the same value for the equivalent height: which is a greater height than the refracted ray ever reaches. Appleton's paper was communicated to the U.R.S.I. in September, 1928, and later to the Physical Society.

Note on the Determination of the Ionisation in the Upper Atmosphere.—J. C. Schelling. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1471–1476.)

The pulse-time, earth-angle, and shift of interference fringe methods for measuring the effective layer height lead substantially to the same result for short waves. Pedersen states that the last method gives apex-height values which are too small. This would be the case if the measurement gave the total number of wavelengths in the path. The writer, however, maintains that none of the three methods does give this total, and that all three give heights which are too great. He then describes a difficult but direct method for obtaining the total: starting at a very low frequency, and gradually working upwards, the fringes at a receiver one or two hundred kilometres away would be counted. Each fringe would represent the gain of one wave in the overhead path as compared with the number—also increasing—in the direct path. This number, integrated from zero frequency to the frequency in question, would give the difference in wave numbers for the two paths. Hollingworth has obtained fringes at 20 kc., and even if the tests started no lower than there, the error due to having to take estimates for the still lower frequencies would be very small. Having

obtained the wave number, the height of the apex of the path could be determined by Pedersen's construction (wave number in true path to apex = straight line distance to apex divided by wavelength in vacuo) where the error is small if the initial earth angle is less than 60 deg. The above "prohibitive and unnecessary" experimental procedure can be cut out, however, by the use of an equation connecting the *group* times with the quantities actually measured by the ordinary methods—namely, $T_{g2} - T_{g1} = \frac{d(N_2 - N_1)}{df}$, the right-hand expression (where N_2 and N_1 are the total number of wavelengths in the two paths) being the quantity actually measured. The writer, in the absence of really sufficient data, illustrates his method by applying it to averaged data for four different frequency zones, representing the adapted results of Hollingworth (20 kc.), Bown, Martin and Potter (610 kc.), Appleton and Barnet (750 kc.), and Heising (5,000 kc.). Plotted on a frequency scale, the four equivalent heights fall on a straight line, the equation of which is $H = 80 + 0.0440 f$. The straight line representing the values calculated by the present method, while coinciding with this line at the lowest frequency, slopes up much less quickly, so that—for example—at 5,000 kc. it reaches rather above 192 km. instead of 300 km. The writer also calculates the ionisation on the basis of the earth angles calculated from the original data, showing the results on a height ionisation curve. They assume that collisions and the earth's magnetic field do not greatly affect them; it is suggested that these assumptions are satisfactory at frequencies higher than 2 or 3 megacycles. The curve (for night time) indicates an approximate increase in proportion to the square of the height above 80 km.; reaching a value of 3×10^5 at about 200 km. The writer emphasises that all these calculations are given on meagre data as examples of his method, but suggests that the results "look plausible and are probably more accurate than the original data." He foreshadows a series of echo or fringe experiments at several frequencies from 1,000 to 10,000 kc., the base line being made sufficiently long to avoid initial ray angles greater than 60 deg. from the horizontal.

RÔLE POSSIBLE DE LA DIFFUSION PAR LES ÉLECTRONS DANS LA PROPAGATION DES ONDES COURTES (Possible Rôle of the Diffusion by Electrons in the Propagation of Short Waves).—Ponte and Y. Rocard. (*Comptes Rendus*, 19th November, 1928, V. 187, pp. 942–943.)

To explain his experimental results, T. L. Eckersley imagines a diffusion of short waves by the free electrons of the Heaviside layer: Jouaust and Fabry have also directed attention to such a diffusion (*cf.* Abstracts, 1928, pp. 221 and 578; 1929, p. 39). The writers consider waves of "some dozens of metres" length: their diffusion by the layer, "which has at least some twenty kilometres thickness" would seem to be analogous to that of light by a perfect gas. But to produce the received signals, effects thus calculated would have to be multiplied by 10^5: or—as this may be interpreted—the free electrons must vibrate in groups of 10^5, in phase agreement. The writers thus picture that for some unknown reason the layer is not like a gas of electrons but has a true structure, being made up of "molecules" (each a little cloud of electrons comparatively dense—*cf.* Eckersley's "clouds small in dimensions compared with the wavelength"—*Abstr.*), which repel each other and take up more or less definite mean distances: a structure analogous to that of a liquid. If d (the mean distance between the two "molecules") is of the order of λ, the diffusion may be compared to that of an X-ray by a liquid or a crystalline powder. In the case of the X-ray, there is a very pronounced maximum of diffusion on the generating lines of a cone of revolution having as axis the direction of incidence and as half-angle of apex the angle θ given by Bragg's law $\lambda = 2d\sin\frac{\theta}{2}$. Assuming this to hold for the Heaviside layer diffusion, each little element of the layer will be hit by a direct ray and will diffuse chiefly at an angle θ to the ray. Considering the combined effects of all the little elements, it will be seen that the diffused rays thus produced have an envelope which will ordinarily cut the earth, *at a point which will actually be the limit of the silence zone*—"for there is no diffused radiation inside the envelope": (but *cf.* final paragraph). The writers treat the Hulburt-Taylor results thus: Above $\lambda = 45$ m. (about) there was no silence zone: this leads to taking $d = 22$ m. They then try out their calculations for various assumed effective heights of the layer, and with one particular assumed height they obtain the following skip distances for the wavelengths used by Hulburt and Taylor (16, 21, 32 and 41 metres):—2,400 km. (2,410), 1,500 km. (1,300), 740 km. (710), and 324 km. (325). The brackets give the values actually observed. The effective height which has to be assumed in order to get such an agreement is 360 km. Simple trigonometry gives, as the shortest wave which can pass (*i.e.*, that for which the envelope touches the earth instead of cutting it) the wave of 14 m. The large observed variations in skip distance are explained either by fairly large variations of effective height or by relatively much smaller variations of d. The energy of the diffused rays is accumulated along the envelope, rather as in a caustic curve: the edge of the silence zone should therefore be a region of strong reception, and the slightest variations of height or of d should create correspondingly strong fading. Finally, the energy diffused by an element is not confined to the direction θ: in other directions there is a feeble diffusion which would account for the weak reception found by Eckersley in the silence zone.

RADIO COMMUNICATION AND MAGNETIC DISTURBANCES.—C. S. Wright. (*Nature*, 22nd December, 1928, V. 122, p. 961.)

Henderson's data on the working of the Macquarie Island station during 1914 and 1915 give the days on which the receipt of wireless signals was difficult or impossible—apparently excluding the

days when atmospherics were serious enough to cause the trouble. The writer has tabulated the international magnetic character numbers for each of these "bad" days: the mean number is 1.1 for 1914 and 1.0 for 1915, compared with 0.55 for 1914 and 0.64 for 1915 *for all the days of the months in question.* "This close relation between bad wireless communication and magnetic disturbance is the more surprising because the international character numbers are awarded mainly on the results from the more numerous magnetic observatories of the northern hemisphere. It would be interesting to compare these results with the magnetograms from the Christchurch Magnetic Observatory. . . . These polar regions contain the auroral belts which are highly disturbed magnetically, and world-wide communication along great circle paths will often cross these belts. . . . It may be that close study will enable rules to be laid down as to the best means of round-about communication by relay stations on bad days, analogous to the mariner's rule for avoiding the centre of a hurricane. It may be mentioned that the apparent relation between bad wireless communication from New Zealand and neighbouring parts to Macquarie Island, and magnetic disturbance defined by the international character number, is closer than the relation between this character number and exceptional aurora observed at Macquarie Island."

Fading Curves along a Meridian.—R. C. Colwell. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1570–1573.)

The fluctuations in signal strength of KDKA, Pittsburgh, Pa., were observed through the sunset period of Morgantown, W. Va., which is nearly on the same meridian; any variation at sunset should therefore be due to changes in the Heaviside layer and not to refraction through the earth's shadow. The typical curve for a clear day is rather disturbed during the daylight hours, and after sunset increases and shows considerable fading; that for a cloudy day is uniform during the daylight hours, and the increase after sunset is fairly steady. "These observations indicate a new relation between signal intensity and the state of the atmosphere. Other relations have been noted by Austin (Abstracts, 1927, V. 4, p. 177; also *Proc. Inst. Rad. Eng.*, December, 1924) and Pickard" (Abstracts, 1928, V. 5, p. 519). The new relation can be explained if the layer is assumed to be partially operative even during the daylight hours. On fine days there is a reflected ("sky") wave which interferes with the ground wave, causing a slight fluctuation during the afternoon. After sunset the reflected wave increases in intensity and fading becomes more pronounced. On cloudy days the atmospheric conditions prevent the sky wave from reaching the reflecting layer, and only the steady ground wave is received. "It should be understood, however, that the typical cloudy weather curve can only be obtained in the middle of a cloudy period, and similarly for the fine weather curve. When the weather is changing from cloudy to clear and vice versa, the curves are very irregular and depart from the typical forms."

The Propagation of Air Waves and the Upper Atmosphere.—F. J. W. Whipple. (*Engineering*, 2nd November, 1928, V. 126, p. 562.)

Summary of the paper read before the British Association. The sound of a great explosion can generally be heard at distances exceeding 200 km., but there is, beyond the inner zone of audibility, a zone of silence and, further, a usually incomplete and irregular outer zone of audibility. The waves appear to travel by curved paths through the layers of the atmosphere, rising to heights of 40 and 50 km., at which the velocity seems to be greater than near the ground (agreeing with the Lindemann-Dobson theory). Recent research is described: wind effects interfere with the interpretation of results, but neglecting these, the uniform temperature of the stratosphere seemed, on a particular day, to extend up to 30 km. above the ground.

The Stratosphere over North India.—K. R. Ramanathan. (*Nature*, 15th December, 1928, V. 122, p. 923.)

Sounding-balloon results regarding the height and temperature of the base of the stratosphere, and their remarkable seasonal variations.

Long Wave Radio Reception and Atmospheric Ozone.—K. Sreenivasan. (*Nature*, 8th December, 1928, V. 122, p. 881.)

A reply to Dobson's comments on the writer's suggestion of correlation between reception at Bangalore and European ozone-values (Abstracts, December, 1928, and January, 1929.)

Photochemical Ozonisation.—O. R. Wulf. (*Nature*, 24th November, 1928, V. 122, p. 825.)

Summary of a paper in the *Journ. Am. Chem. Soc.* for October. A consideration of electronic levels indicates that radiation of wavelengths 2,070 and 2,530 A.U. is probably incapable of effecting the dissociation of the O_2 molecule, although Warburg (studying the formation of ozone from oxygen under pressure) obtained ozone by such radiation and concluded that the primary photochemical process was the dissociation of the O_2 molecule. On various grounds the writer suggests that the absorbing molecule is O_4, which dissociates into O_3 and O.

Die Fortpflanzung elektrischer Wellen in Kabeln mit zwei Isolationsschichten (The Propagation of Electric Waves in Cables with two Insulating Layers).—N. H. Frank. (*Ann. d. Physik*, No. 11, 1928, V. 86, pp. 422–434.)

By Sommerfeld's method, the solution of Maxwell's equation is obtained for the case of a wire surrounded (first) by two co-axial insulating layers of different dielectric constants; and (secondly) by a conducting sheath. Among other assumptions the wavelength is taken to be long compared with the thickness of the cable. The formula is confirmed experimentally by the use of Pedersen's method for measuring short times by Lichtenberg figures, which shows itself applicable also to the

measurement of dielectric constants. A surge is distributed between two electrodes on a photographic plate: from the position of the line of separation of the two electrical figures on the plate, small differences in travel along the two paths are measured.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

THE ULTRA-VIOLET LIGHT OF THE SUN AS THE ORIGIN OF AURORÆ AND MAGNETIC STORMS.—H. B. Maris and E. O. Hulburt. (*Nature*, 24th November, 1928, V. 122, pp. 807–808.)

Preliminary conclusions from a theoretical investigation of the outlying regions of the earth's atmosphere and of the effects of sunlight on those regions. The calculations confirm the idea that above 100 km. the daytime temperatures increase with height, till at 300 or 400 km. temperatures of 1,000 deg. K. seem reasonable. Above 400 km. the atmosphere becomes very rare, and the free paths of the particles would be practically infinite but for the restraining effects of gravity and of sunlight. Some of the particles (atoms or molecules), under the influence of upward thrusts from thermal impacts below, may reach heights of 10,000 km. Some atoms, by "collision of the second kind" with outlying atoms excited by short-wave ultra-violet light, may receive a velocity high enough to send them beyond the normal gravitation of the earth: so may other atoms which absorb the energy of recombination of a positive ion and an electron. Such high-flying atoms may hasten out towards interplanetary space, but soon become ionised by the ultra-violet radiation and are caught by the earth's magnetic field; as ion pairs they are constrained to spiral around the line of magnetic force, eventually being brought back to earth. If the magnetic line ends in night latitudes (as in polar regions after sunset), the ion pairs, plunging to the lower levels, hand over their energy of recombination to the atmosphere of those regions; this energy going into heat or, if the conditions are suitable, reappearing as light such as the auroral display. Quantitative estimates based on reasonable assumed values indicate that enough of the solar ultra-violet energy is carried to a zone 20 deg.–30 deg. from the magnetic poles by high-flying ion pairs, ejected to heights of 20,000–40,000 km., to supply (from a quiet sun) a mild auroral display; this is in keeping with the fact that the aurora occurs on a rough average two or three times a week throughout the year. Other auroral characteristics fit in with the theory. When the sun becomes active, the magnetic effects of the high-flying ions become pronounced and result in magnetic storms. If 1/10,000 part of the solar surface (normally at 6,000 deg.) is removed and the black body radiations from regions at 30,000 deg. exposed, the total ultra-violet energy in the wavelengths 500–1,000 A.U. is increased by 10^5, with a corresponding increase of high-flying ions; whereas the solar constant increases only 1 per cent. (Actually, in times of solar activity, this variation is found to be 3 per cent. or more, and temperatures above 30,000 deg. are indicated.) Calculations show that the blast of solar ultra-violet light pictured above produces enough high-flying ions to give (by their flow under the combined action of gravity and the earth's field) a current of 10^6 A. for an hour or so, causing a magnetic field of the order of 10^{-3} gauss simultaneously over the whole earth—of the right order of magnitude for the first phase of a world-wide magnetic storm. The high-flying ions descend to form diamagnetic concentrations in the zones about 25 deg. from the magnetic poles. If the blast of ultra-violet light continues with lessening intensity for a day or two, these concentrations would wax and wane by day and night, causing changes which agree "in practically every detail" with the observed complicated diurnal storm variations.

THE ULTRA-VIOLET LIGHT OF THE SUN AS THE ORIGIN OF AURORA AND MAGNETIC STORMS.—S. Chapman. (*Nature*, 15th December, 1928, V. 122, p. 921.)

A criticism of the letter abstracted above. The terrestrial effects of the occasional sudden blasts of ultra-violet light would be felt almost immediately; and would depend relatively little upon the position of the emitting area on the sun's disc. The latter consequence appears incompatible with the marked tendency for abnormal terrestrial magnetic conditions to recur after about 27 days—the rotation period of the sunspot zone relative to the earth: indicating that the cause must be something which travels outwards from particular disturbed areas in laterally limited beams—almost certainly corpuscular. Accumulating evidence indicates that the material of the stream occupies a time of the order of a day in passing from the sun to the earth. This appears incompatible with the former consequence. Apart from these fundamental objections, the writer criticises the proposed explanations of the two phases of a magnetic storm. He refers to Gunn's recent diamagnetic theory of the solar diurnal magnetic variation (Abstracts, 1928, V. 5, p. 578) with which also he finds himself in disagreement, and ends by promising to publish shortly a new discussion of the theory of magnetic disturbances, assuming the cause to be a neutral ionised stream (as suggested by Lindemann).

ÜBER ELEKTROMAGNETISCHE STÖRUNGEN (On Atmospherics).—F. Schindelhauer. (*E.N.T.*, November, 1928, V. 5, pp. 442–449.)

The writer (of the Meteorological Magnetic Observatory, Potsdam) gives a number of curves representing his Potsdam results on atmospherics; then, combining these with data put at his disposal by Watson Watt, representing similar observations at Ditton Park, Lerwick and Aboukir, draws his own conclusions, which he summarises somewhat as follows: Since the directions of maximum electromagnetic disturbance lie either in the direction of the earth's magnetic lines of force or at right angles thereto, the view is taken that the majority of atmospherics originate, at great heights in the upper atmosphere, in field changes caused (1) by those electrons arriving from the sun which are constrained by the earth's field to form an equatorial ring-stream, and (2) by what he calls the "horizontal current-eddies" in the heights of the Heaviside layer, maintained only on the day

light half of the earth by ultra-violet radiation, and therefore moving over the earth from E. to W., attaining their greatest magnitude in summer. They are due to the conducting layer suffering, from time to time, displacement in the magnetic field, owing to movements of the atmosphere. Atmospherics caused by (1) are "clicks": they come at night, from the direction at right angles to the magnetic lines of force; at daybreak the horizontal eddy in the Heaviside layer begins to screen the earth from the effects of these higher impulses, the "clicks" begin to decrease, while simultaneously the "grinders" due to cause (2) begin to come in from the N.-S. direction. This theory fits in well with the daily and yearly variations in direction and frequency of atmospherics.

ATMOSPHERIC OSCILLATIONS SHOWN BY THE MICROBAROGRAPH.—N. K. Johnson. (*Nature*, 8th December, 1928, V. 122, p. 908.)

Summary of paper read before the Roy. Met. Soc. Regular wave-like records are obtained representing oscillations of atmospheric pressure ranging from about 6 minutes to an hour, with a marked maximum for a period of about 10 minutes.

ON THE ASSOCIATION OF THE DIURNAL VARIATION OF ELECTRIC POTENTIAL GRADIENT IN FINE WEATHER AND THE DISTRIBUTION OF THUNDERSTORMS OVER THE GLOBE.—F. J. W. Whipple. (*Nature*, 8th December, 1928, V. 122, p. 908.)

Summary of a paper read before the Roy. Met. Soc. Observations of the gradient in polar regions and at sea give results consistent with C. T. R. Wilson's suggestion that the connection between the upward currents produced by thunderstorms and the downward currents elsewhere is *via* the Heaviside layer.

MOLECULAR HYDROGEN IN SUNSPOTS.—G. Piccardi. (*Nature*, 8th December, 1928, V. 122, p. 880.)

From spectroscopic photographs the writer deduces the presence of molecular hydrogen in sunspots.

CHARACTER FIGURES OF SOLAR PHENOMENA.—(*Nature*, 22nd December, 1928, V. 122, p. 974.)

A paragraph announcing the first number of a Bulletin issued from Zurich under the auspices of the International Astronomical Union.

TRANSMISSION.

SECRECY SYSTEM FOR SIGNALLING.—(*N. Zealand Patent* 61093, *Standard Telephones and Cables, Australasia*, pub. 16th August, 1928.)

A speech wave separately modulates two carrier waves of such frequencies that the resulting upper side bands, for example, are contiguous, and when selected and added form a band of frequencies double the width of the speech-band, the carrier waves being suppressed in the modulators. This band, of double speech-band width, modulates a *variable-frequency* carrier wave, which is suppressed in the modulator. The resulting upper side-band, for example, is a "wobbling" band, its width in the frequency scale being twice the width of the speech frequency-band at each instant, and its position in the frequency scale varying in synchronism with the frequency-variation of the carrier wave. This "wobbling" band is filtered through a band-pass filter which passes only the speech-band width with its centre (*e.g.*) midway between the frequency limits of the wobbling band. The band thus passed is radiated, and contains components representing all the components of the original speech wave but permuted in a cyclic order. At the proper receiving station, where all the various factors are known, this band is demodulated separately by two waves of variable frequency, the one having a frequency equal to the algebraic sum of the variable carrier frequency and the lower of the two fixed carrier frequencies, the other the algebraic sum of the variable carrier frequency and the higher of those two fixed carrier frequencies. These two demodulations, when combined, yield the whole of the speech-wave components plus distortion components, some of which are filtered out, the remainder not rendering the received speech unintelligible. *Cf.* January Abstracts, under "Miscellaneous."

ÜBER DIE NEUERE ENTWICKLUNG DES MASCHINENSENDERS FÜR KLEINE WELLENLÄNGEN (New Developments in H.F. Generators for Short Wavelengths).—W. Hahnemann. (*E.N.T.*, November, 1928, V. 5, pp. 431–437.)

These improvements in the Lorenz-Schmidt system were called for by the needs of Broadcasting (*i.e.*, transmission on wavelengths under 1,000 m.). (1) Suppression of harmonics and partial frequencies close to the transmitting frequency. The greater the frequency multiplication the nearer do these come to the main frequency. For the wavelengths in question, requiring a multiplication of 100, the process must be done in two stages, and the filtering and rejecting must be applied in each stage. To reduce the interfering waves to the required amplitude (1/1,000 or less of their original value) only the use of the most advanced methods of damping-reduction can suffice. The apparatus and methods successfully employed are illustrated. (2) Improving the life of the frequency-transformer. With the previous design, this life was short owing to carbonisation of the very thin iron lamellæ even with apparently adequate oil-cooling. This trouble has been completely overcome by a new design in which the thin sheets are made into "spiral discs" abreast of one another with spacing between. The path from the inside of the sheet to the outside (oil-cooled) is only 1 mm. (3) Improvement in speed-regulation. This was attained by adding refinements to the Lorenz-Schmidt governor (see these Abstracts, and also January) which cut out all sparking at the spring contacts. The arrangement shown here includes a control relay and an auxiliary dynamo as a "relay-machine," for fine regulation, and another relay and a regulating motor (working a field resistance in the main motor circuit) for coarse regulation. (4) Cutting out the "trill" effect. This effect is found chiefly in heterodyne reception, and is not obvious in telephony reception. But certain

distortion observed in Broadcast reception was traced down to this " trill " effect. Oscillographic investigation showed that the trill was due to very small (one in 6,000) periodic variations of transmitter-frequency, and after many false starts the cause was proved to be vibrations of the H.F. dynamo stator—of an amplitude amounting to about 1/40 mm. A new, more solid design, combined with a very careful balancing of the rotor, completely cured the trouble. The combined results of these researches have, it is claimed, made the system equal to the very latest valve-transmitters in the Broadcasting region of wavelengths.

Über eine Methode zur Erzeugung von sehr kurzen elektromagnetischen Wellen (A Method for the Production of Very Short e.m. Waves).—A. Záček. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, p. 172.)

Referring to Yagi's (and Okabe's) " Magnetron " method (Abstracts, 1928, V. 5, pp. 519 and 399, and 1929, p. 42) the writer mentions that he obtained the same results with an identical method four years ago. He quotes his own words in the Czech " Zeitsch. f. Math. u. Phys." of 1924 ; extracts from which are : A straight filament cathode and concentric cylindrical anode—no grid. . . . A magnet coil whose axis is the filament. . . . A gradually increasing current is passed through the coil, and the (hitherto) radial electron paths are bent so that the electrons impinge on the anode no longer normally but at an acute angle, acuter as the magnetic field increases. . . . At a critical value of field they no longer reach the anode but curve back to the cathode, as can be seen by a milliammeter in the anode circuit. . . . If an oscillatory circuit is connected between anode and cathode, and the magnetic field kept constant just past the critical value, oscillations are produced in the circuit. . . . The wavelength is independent of the oscillatory circuit (actually a pair of parallel straight wires—" antennæ "—one connected to the cathode and one to the anode) : only the intensity of the oscillations depends on the lengths of the " antennæ." The wavelength depends on diameter of anode, anode voltage and the intensity of the magnetic field. The intensity of the oscillations reaches its maximum at a certain field intensity H_m dependent on the anode voltage E_a ;

then, approximately, $\lambda = \frac{a}{H_m}$ and $\lambda = \frac{A}{\sqrt{E_a - B}}$,

where a, A and B are constants. The shortest wave obtained at the time was about 29 cm. (E_a = 300 v.).

RECEPTION.

Empfangsstörungen durch ein Heizkissen (Interference due to an electrically heated cushion).—(*E.T.Z.*, 29th November, 1928, p. 1756).

The automatic cut-out of such a cushion or pillow causes, by its sparking, serious intermittent disturbances at intervals of 15 seconds or so. A mica condenser of 10,000 to 20,000 cm. capacity cures the trouble, but it must be connected straight on to the regulator inside the cushion.

A Note on Some Interfering Oscillations Experienced in a Supersonic-Heterodyne Receiver.—R. L. Smith-Rose. (*E.W. & W.E.*, December, 1928, V. 5, pp. 673–676.)

These interferences were encountered in the development of a highly sensitive receiver for the reception of C.W. Signals : their origin and the methods of eliminating them are described. Intermittent action of a valve oscillator due to " squegging " causes one kind, particularly liable to be found—it seems—if one valve is made to serve the dual purpose of first oscillator and first detector : a bad practice adopted by some manufacturers. A second kind is produced by the self-oscillation of the intermediate frequency amplifier. A third, more subtle kind, can only be distinguished from an incoming signal by lack of direction : it is due to the second local oscillator giving an impure oscillation, so that under certain conditions a harmonic from here gets into the primary or secondary receiving circuits.

A Double Super-heterodyne : A Description of a Receiver built by the Author.—J. F. Ramsay. (*E.W. & W.E.*, December, 1928, V. 5, pp. 669–672.)

The article begins by discussing why the super-heterodyne receiver is not more popular in England : a bad reputation regarding quality may be one cause—this is the fault of manufacturers who strain to get a maximum gain per stage : another cause is that we obey admonitions to " cultivate the local station." The double super-heterodyne described and illustrated, when receiving short waves say of 45 m., transforms to 500 m. and amplifies, then transforms again to 2,000 m. and amplifies again ; when thus used it employs 10 valves and two oscillators : broadcast from Schenectady can be made to overload the loud speaker—it has been received without an aerial but was barely intelligible. No screening has been found necessary.

The Distortionless Diode : Practical Applications of the Two-electrode Rectifier.—H. F. Smith. (*Wireless World*, 12th December, 1928, V. 23, pp. 783–786.)

A 3-electrode valve used as a diode rectifier, the grid being merely employed to neutralise the space charge (by a grid voltage of some 9 or 10 V), has the advantages of giving a rectifier output strictly proportional to the input voltage over a wide range, and of requiring no high tension, so that it is completely isolated from the anode circuits of the L.F. valves : the possibility of low-frequency reaction is thus very considerably reduced. This is of special importance in cases where the anode voltage is derived from an eliminator. Its disadvantages are that it does nothing towards magnifying the applied signal voltages, and that reaction from the detector anode circuit is no longer obtainable. Thus for long distance reception an extra H.F. stage is almost essential. But for good reproduction from the local station the diode, combined with a two-stage L.F. amplifier, is excellent. Its action is improved by a slight positive bias on the anode, derived from a potentiometer across the filament battery. Like a galena crystal, the diode puts a heavy load on the tuned circuit preceding it,

and the anode connection should be made to an anode-tap forming (as a general rule) only about one-third of the tuning coil. Various circuits are given showing the use of the diode under the best conditions for long distance work.

THE EFFECT OF FREQUENCY ON THE VALUE OF HIGH RESISTANCES OF THE GRID LEAK TYPE.—W. Jackson. (*E.W. & W.E.*, December, 1928, V. 5, pp. 677–679.)

The effective resistance of the usual type of grid or anode resistance decreases, as the frequency increases, by reason of its self capacity: this reduction becomes pronounced at frequencies approaching 10^6 p.p.s. and explains the unsatisfactory voltage amplification of resistance-capacity-coupled amplifiers at high frequencies. The present paper investigates whether the actual ohmic resistance varies to any marked extent with the frequency, quite apart from any variation of effective resistance due to the self-capacity. A series of measurements on several commercial types shows that such a variation does occur, " in some cases to a greater extent than would have been expected ": in some types the resistance increases, in others it decreases, with increase of frequency. The magnitude of the variation may be indicated by two examples: for a change of wavelength from 7,000 to 300 m. (approx.), one type increased from 0.239 meghom to 0.263, while another decreased from 0.368 megohm to 0.208.

ÜBER DIE DYNAMIK DER SELBSTTÄTIGEN VERSTÄRKUNGSREGLER (The Dynamics of the Automatic Amplification-Regulator).—K. Küpfmüller. (*E.N.T.*, November, 1928, V. 5, pp. 459–467.)

From the Siemens & Halske laboratories. All " indirect " types of regulating (see H. F. Mayer, below) are liable to oscillation: a state of stable balance can only exist under certain conditions. These conditions are here investigated mathematically and various conclusions arrived at: the stability of a system is greater in proportion to the slowness of its regulating-action: the use of long series of filter chains in such a system leads to liability to oscillation.

ÜBER AUTOMATISCHE AMPLITUDENBEGRENZER (Automatic Amplitude Limiters).—H.F. Mayer. (*E.N.T.*, November, 1928, V. 5, pp. 468–472.)

This paper (from the Siemens-Halske laboratories) begins with a short historical survey in which a number of British and American patents are cited (1914-1925). It then defines two classes of regulator—the direct and indirect: in the former, the unregulated control frequency is employed for regulation, the receiver being thus controlled from the input end: while in the latter the control is from the output end, the control frequency being itself regulated at the same time. A third class, the true " amplitude-limiter," is independent of any control frequency, being used in circuits where the amplification has to be controlled directly by the amplitudes of the signal currents—*e.g.*, Broadcast transmitters, microphone-loud speaker installations, or recording apparatus for picture telegraphy, talking films or gramophone recording. More recent patents are here cited and the Siemens-Halske arrangement is described, of the indirect type. The indirect type has the advantage that the control can never cut out the main amplifier entirely, since it is itself controlled; whereas this can easily happen with direct control, unless special precautions are taken against such a result. On the other hand, the direct method has the advantage of providing no back-coupling, which (in the indirect type) is a source of oscillation. The influence of operating time on satisfactory performance is discussed, and the factors governing it; also the question of duration of the " after effect " (depending chiefly on the size and perfection of insulation of the control condenser; also on the insulation of the grid-leak condenser of the controlled stage), and its results and uses.

AERIALS AND AERIAL SYSTEMS.

DIE BÜNDELUNG DER ENERGIE KURZER WELLEN (Beam-Concentration of the Energy of Short Waves).—O. Böhm. (*E.N.T.*, November, 1928, V. 5, pp. 413–421.)

A communication from the Telefunken laboratories. After dealing first with the simple di-pole aerial and its directivity, it treats the simple systems derived from this—the straight line type throwing the beam fore and aft, and the plane type projecting at right angles (in both cases it is stated that it is not yet certain whether the earth functions as a dielectric or as a metallic surface; with the frequencies in question—3 to 20 megahertz—the capacitive resistance of the earth is probably of the order of an ohmic resistance). Both types give equal concentration, the increase of signal strength at the receiver being in both cases proportional to the total number of elements. The cutting out of the backward radiation is then dealt with; the received energy is still proportional to the number of elements in the aerial system plus screen. Various special polar curves can be produced at will by suitable adjustment of spacing, phasing, and current-distribution: a particular one is illustrated having two very concentrated main beams separated only by a very small angle. This form, produced by so feeding a plane system that one half oscillates oppositely to the other, is about to be used at Nauen for simultaneous communication with Buenos Ayres and Rio de Janeiro. The reciprocal action of a beam-receiving aerial is then discussed: theoretically, the best use of a given number of di-poles is to employ them half at the sending and half at the receiving end. But since in the latter position they do not increase the ratio signal/interference unless the chief sources of interference fit in with their polar diagrams, the question is not so simple. Additional importance, however, attaches to the extended beam-receiving aerial by reason of its effect in minimising fading. The receiving reflector, also, is of the greatest importance for cutting out the backwards-round-the-earth signals. A striking record strip is shown of Morse Signals from Buenos Ayres at Geltow, received on a simple di-pole and on an eight-wire reflector-beam system respectively: interference, echoes and fading are clearly evident

on the former and practically invisible on the latter. With a 12-wire antenna and a 12-wire reflector, the strength of signal was trebled and the speed of communication multiplied by six. Oscillograms (using no reflector) are also given showing the interference by these echoes: some of these are stronger than the direct signal; another oscillogram shows the presence of the Doppler effect due to the lengths of the paths varying during the transit. The paper is based on work undertaken by the Telefunken Company, to see how far actual results agreed with theory and to decide whether horizontally or vertically polarised beams were the most effective. W. Moser has published his account from the transmitting point of view (see below). It was found that the horizontally polarised were the most useful, giving signals twice as loud as the vertically polarised. Several horizontal di-poles one above the other improved matters still more. All this agrees with the theory worked out by Lassen and the results of Meissner and Rothe with a rotatable parabolic mirror (Abstracts, 1928, V. 5, p. 637). The exhaustive tests led to the design of transmitting and receiving aerials on a plan which is described and schematically pictured.

Die Übertragung der Energie vom Sender zur Antenne bei kurzen Wellen (The Feeding of Energy from Transmitter to Aerials, for Short Waves).—W. Moser. (*E.N.T.*, November, 1928, V. 5, pp. 422–426.)

Deals in detail with the method of feeding the power to the aerial systems described in Böhm's article (see above). Parallel wires in a common metal sheath and strip conductors were tried, but the paper confines itself to concentric tubes and unsheathed parallel wires. The two most important points are loss through radiation (which may, moreover, cause field-distortion) and through heating. The former is absent in the case of the concentric tube feeders, and even with parallel wires can be made negligible. The latter (heating of feeder, joints, dielectric losses in insulators and earth-losses) must be reckoned with, and limit the distance of aerial from transmitter and the dimensions of the aerial system itself. Measurements of these losses, for parallel wire feeders, present difficulties at the frequencies in question (wavelengths 10–30 m.). The methods of Arkadiew and Kartschagin and of Roessler are referred to, but the method used and described (for both types of feeder) is a new one due to Roosenstein. It depends on the measurement and plotting of the voltage distribution at the potential node near the beginning of the feeders, when standing waves are excited in these; the damping being calculated from the shape of the curve. With concentric tube feeders, there must be holes at suitable intervals along the earthed outer tube to enable these measurements to be taken. Tables of results are given showing that the measured losses are always (sometimes much) greater than the calculated losses, since these do not allow for the effects of earth, coating of oxide, and insulators; nor for the resistance of the joints (in tube feeders especially). Nevertheless tube feeders of 100 m. length can have an efficiency of 97 per cent. and those of 1 km. length one of 77 per cent. Losses in feeders depend on the proportioning of the total effective impedance. If this is correct, only travelling waves exist in the feeders; otherwise standing waves, with increased losses, are superimposed. The use of transformers is of service here: various arrangements of these are shown: the simpler—auto-transformer—being really less serviceable than the more complex. But a special connection is shown which partly or wholly dispenses with transformers, the impedance of the feeders being so adjusted that the impedance of the branches is equal to that of the main feeder. The impedances can be altered considerably by changes in spacing and diameters of the conductors, as is shown by the curves.

Über Drahtreflektoren (Wire Reflectors).—A. Gothe. (*E.N.T.*, November, 1928, V. 5, pp. 427–430.)

A paper based on the Telefunken tests (see above two abstracts). It deals first with a simple single wire reflector ($\lambda/4$ behind a single aerial) excited only by radiation from that aerial. A reduction of the backward radiation could only be obtained when the natural wavelength of the reflector wire was greater than the transmitting wave: otherwise the backward radiation was increased (*cf.* Yagi's "directors," Abstracts, 1928, V. 5, p. 519). With the optimum reflector length the backward beam could be cut down to one-third. Two reflector wires, $\lambda/4$ away from each other and from the aerial, cut it down to one-sixth. More than two gave no better effect. Preliminary results of Sommer's theoretical investigation of the radiation-coupled reflector are given, based on the Hertz field-equations applied to a half-wave dipole. Between $\lambda/8$ and $\lambda/2$ from the aerial, the reflector is in a zone where the three fields (near-field, transition and distant fields) are of the same order of magnitude. A curve is given, showing the calculated falling off of the current induced in the reflector with increase of distance from $\lambda/16$ to $2\lambda/3$: and the change of phase difference, in the case where reflector and aerial are tuned together. Even at $\lambda/8$ the induced current is markedly smaller than the aerial current: yet the necessary phase-difference of 270 deg. can only be obtained at about $5\lambda/12$: or by detuning—which reduces the reflector current still more. For a single aerial, curves show that the best compromise is a distance of $\lambda/8$; but with a multiple system the mutual reactions make $\lambda/4$ the optimum distance. If the object of the reflector were merely to increase radiation in the right direction, a 90 per cent. reflector effect would be quite enough: this can be attained with the radiation-coupled method. But the main object is the cutting out of echo signals: in view of the effects of fading, the mean ratio of indirect to direct signals should—for perfect communication—be not more than 1 to 50. In times of strong echoes, this involves a reflector effect of at least 100 to 1: this is beyond the scope of radiation-coupled reflectors. But it can be reached and surpassed by the use of auxiliary coupling in the form of a double transformer. With this arrangement the tuning and phase-regulation no longer involves altering the length of the reflector wires, since each secondary has a condenser in series and a variable coupling to the primary. It is thus possible to interchange the functions of aerial and reflector, and in this way to

reverse the direction. The method of auxiliary coupling is equally effective with receiving and transmitting systems.

Die Wirkungsweise von Reflektoren bei kurzen elektrischen Wellen (The Action of Reflectors on Short Electric Waves).—G. Gresky. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 149–162.)

An investigation, carried out under the auspices of A. Esau, on the behaviour of cylindrical-parabolic and plane reflectors, for wavelengths of 260–437 cm., in relation to their various dimensions. The transmitter used as its circuit condenser a glass plate copper-coated; plates with coatings stuck on were found to be useless for prolonged service. The valve was a Telefunken RS.19, socketed and provided with thick leads. Anode supply was 500 frequency A.C. at 2,000 V. The aerial was a straight vertical wire with a hot wire ammeter at its mid-point: it was inductively coupled to the transmitting circuit and tuned to oscillate to the half wave. The reflectors were composed of wires of length l stretched vertically on a rotatable frame and spaced by a gap d. The receiver (at a distance of about 170 metres) consisted of a similar di-pole aerial with detector (Seibt) and galvanometer (a Zeiss Loop galvanometer which was found very suitable on account of its great damping) shunted by a variable resistance. The detector was calibrated by a hot-wire air thermometer (Scheibe). After each measurement the constancy of the detector was checked by turning the reflector back to the "zero" position. The detector was found to remain constant for days at a time, giving the same reading for the same reflector position. For the parabolic reflector, the optimum ratio focal length/wavelength was found to be 0.27; for the plane reflector the optimum ratio distance between aerial and screen/wavelength was 0.20. The parabolic is much superior to the plane in directivity and "magnification" (ratio max. energy of transmitter plus reflector to max. energy of transmitter alone). Of parabolic reflectors two kinds are possible: if l is made long (about as long as λ) and d is made small ($\lambda/30$), the nearest approach to a metal surface is obtained. This is the "untuned" reflector. If $l<\lambda/_2$, and d is made about $\lambda/8$, the "tuned" reflector is obtained. (If $d = 20$ cm., the two types merge). The untuned gives results better by a small percentage than the tuned, in directivity, magnification and absence of backward radiation; but the tuned is preferable in practice because of its smaller height. In either type the opening should not exceed 1.5λ. All this is based on a wave of 298 cm. which was used as the working wave. Results were confirmed by qualitative observations at distances of 4 and 18 km.

VALVES AND THERMIONICS.

Die Feldkräfte auf die Glühdrähte von Elektronenröhren (The Field Forces on the Filaments of Thermionic Valves).—K. Pohlhausen. (*Wiss. Veroff. a.d. Siemens Konz.*, No. 1, 1928, V. 7, pp. 109–119.)

Formulæ are derived for the calculation of the electrostatic forces on the filaments. It is concluded that as a general rule the introduction of a central support is without value. In a H.T. rectifying valve with ten filaments, a voltage of 100 kV. produced a force of 2.12 g. per cm. length of one filament. A central support raises the force by 7 per cent.

Vacuum-Tube Production Tests.—A. F. Van Dyck and F. H. Engel. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1532–1552.)

A description of the methods and apparatus employed by the authors (of the Technical and Test Department, Radio Corporation of America) in the testing of valves in large quantities.

Three-electrode Valves with Filaments for A.C. Heating. (*French Patent* 640,184, *E. C. and A. Grammont*, pub. 7th July, 1928.)

Two parallel filaments are used cross-connected so that they are fed in opposite directions. They can, if desired, be used in conjunction with the usual "centre point tapping" (of transformer secondary or special resistance) to the grid.

Physik der Glühelektroden (The Physics of Hot Electrodes).—W. Schottky and H. Rothe. (*Handbuch d. Experimentalphysik*, Part 2, V. 13, 1928, pp. 1–281.)

Herstellung der Glühelektroden (Construction of Hot Electrodes).—H. Simon. (*Handb. d. Exp.-physik*, Part 2, V. 13, 1928, pp. 283–340.)

Technische Elektronenröhren und ihre Verwendung (Commercial Electronic Valves and their Application).—H. Rothe. (*Handb. a Exp.-physik*, Part 2, V. 13, 1928, pp. 341–482.)

DIRECTIONAL WIRELESS.

Wireless Beacon at Start Point. (*Nature*, 8th December, 1928, V. 122, p. 898.)

A paragraph on the seventh beacon of its kind just completed by the Marconi Co. for Trinity House. Main details are mentioned.

Über Fehlweisungen der Funkpeilung in Abhängigkeit von der Wetterlage (Direction-finding Errors and their Dependence on Weather Conditions).—P. Duckert. (*E.N.T.*, November, 1928, V. 5, pp. 438–441.)

After referring to seven previous papers in which (since 1925) he has published the results of his investigations into the influence of atmospheric conditions on the direction and strength of wireless signals, the writer describes how nearly he has been able—in the observations on which the present paper is based—to obtain the ideal conditions which render those observations perfectly reliable. They lead to the conclusion that, so far as daytime errors and rapid direction-variations are concerned, they occur always and only (with very few exceptions) when the meteorological and aerological conditions have produced—between transmitter and receiver—an unstable surface of discontinuity, so that a

temperature inversion is present together with a specific humidity increasing (or at any rate not decreasing) upwards in the bottom 200 metres. The surfaces which affect the loudness of signals (usually particularly stable formations) have almost no appreciable effect on direction. The unstable ones, on the other hand, have the invariable result that if at one station the direction found for the second station makes too great an angle with N (compared with the great circle), at the second station the direction of the first will make an angle with N too small by practically exactly the same amount: so that the "bearing beam" (to coin a name) appears to follow a symmetrically curved path between the two stations. The symmetry at the two ends is only upset by some local source of error—a local re-radiated field, for example.

Referring to twilight and night signals, the writer mentions Falckenberg's recent pronouncement that the greatest bearing-variations appear one to two hours after sunset. He then announces the preliminary results of his own observations at these times, namely, that whereas in daytime no variations of signal strength accompanied the bearing-variations, in twilight and at night the latter were always attended by simultaneous fading. It thus seems that the interference effect between ground and space waves (which cause both fading and twilight bearing-deviations) have nothing to do with the daytime deviations, which are wholly governed by the meteorological influences described. It may be of interest to remember that it is just this type of surface of discontinuity which provides a great proportion of atmospherics—as can be seen from automatic direction-finder records of atmospherics.

ACOUSTICS AND AUDIO-FREQUENCIES.

High-Quality Reproduction of Music.—H. Backhaus. (*Siemens Zeitschr.*, May, 1928, V. 8, pp. 298–304.)

An article based on the use of the Siemens "Public Address" system at the International Music Convention at Geneva in 1927.

Improvements in Telephone Receivers.—R. G. E. Bury. (*French Patent No.* 641,201, pub. 30th July, 1928.)

A simplification of the magnet system which claims to be cheaper and no less effective. The received currents flow through a single cylindrical bobbin whose iron core shunts the magnetic circuit between the open ends of a fixed U-shaped magnet.

Über neuere akustische . . . (Latest Work on Acoustics, and in particular Electro-acoustics).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 173–179.)

Penultimate instalment of this long paper. Electrical recording of gramophone records is dealt with, particularly the work of Maxfield and Harrison, whose treatment (as well as Kellog's) of electrical reproduction is also referred to. A table of equivalent mechanical and electrical quantities is given. Engl and Rankine's work on Talking Films is briefly mentioned, and the "ultra-phone principle" of gramophone-reproduction is outlined in which two sound-boxes are used with a time-difference of about 1/10 sec. for the two needles, producing a subjective increase in loudness. The production of supersonic waves is next treated briefly (Langevin, Pierce, Wood and Loomis) and the rest of the article deals with the acoustics of musical instruments: particularly the work of Raman on the theory of stringed instruments, and the results in sound-analysis of Stumpf and Backhaus. The latter devotes himself to the violin, and various curves are reproduced showing the characteristics of violins by famous makers. His results contradict the previous views of Hewlett (based on Rayleigh disc tests) that a violin is better the greater the energy concentrated in the fundamental as compared with that in the overtones.

The Transmission of Sound through Sea Water.—J. H. Service. (*Journ. Franklin Inst.*, December, 1928, V. 206, pp. 779–807.)

Introduction: Work of Heck and Service on Speed of Sound in Sea Water. British Admiralty Tables: Comparison with the Tables of Heck and Service. Measurements by the German Survey and Research Ship "Meteor." Tests of H. and S. Tables by U.S. Coast and Geodetic Survey (Piano Wire and Echo Soundings). Determination of Sound Speeds for Echo Soundings in U.S. Coast and Geodetic Survey. Ditto, for Radio-acoustic Position Finding. Experience with Radio-acoustic Position Finding in Various Regions. Discussion: Why is the transmission of sound in radio-acoustic work good to excellent off the coasts of Washington and Oregon, and poor to fair off the coasts of N. Carolina and Florida? Phenomena observed in connection with radio-acoustic position finding and echo sounding; parasite noises; the work of Brillié; shielding the hydrophone; wall thicknesses nearly an exact multitude of wavelength. Relative Attenuation with distance of Sounds of great and of small Amplitudes. Variation of Speed with Intensity. Appendix: Methods in use in the U.S. Coast and Geodetic Survey for Measurement of Depth of Water. Bibliography.

Electrostatic Microphone - Telephone. — L. Lévy. (*French Patent No.* 640,870, pub. 24th July, 1928.)

The attraction of the membrane by the electrode is balanced by the attraction of a second electrode on its other face; this arrangement allows the membrane to be very light, with very little inertia and very slight rigidity; resonances due to the natural period of the membrane are thus avoided. The thin films of air between membrane and electrodes produce a damping which is easily adjustable by the size of the holes connecting interior with exterior.

Les Instruments de Musique à Oscillations Électriques: Le Clavier à Lampes (Electrically oscillating musical instruments: the valve keyboard).—A. Givelet. (*Génie Civil*, 22nd September, 1928, V. 93, pp. 272–276.)

An article which takes very seriously the future possibilities of such instruments, and reviews the

progress already made. The diagram is given of a single keyboard controlling simultaneously hautbois, saxophone, flute and trumpet effects, by the use of a loud speaker and suitable filter for each timbre. Percussion instruments such as the piano can also be represented by a suitable circuit. The cathode ray oscillograph is of great use in the research.

PHOTOTELEGRAPHY AND TELEVISION.

ZUR FRAGE DES BILDRUNDFUNKS (The Question of Picture Broadcasting).—A. Korn. (*E.T.Z.*, 29th November, 1928, pp. 1747–1748.)

The question, much discussed in the Press, whether the time is ripe for picture broadcasting is here treated. The writer considers that satisfactory television will not be attained (except in the laboratory) until a new advance in technique is made which will give, with simple apparatus, several hundred thousand signals per second. Till then, the best that can be done is to divide the image up into 2 or 3 thousand elements at most. Such television (of which he has not a high opinion) can be broadcast; he rather fears that the public will be disappointed. But he admits that even such poor television has two advantages over still picture-broadcasting—the interest is much greater, and the eye supplies, subjectively, the lacking details far more than it does in still pictures.

BEGINN DER VERSUCHSWEISEN BILDRUNDFUNKVERSUCHE IN DEUTSCHLAND (Preliminary Trials of Picture Broadcasting begin in Germany).—(*E.N.T.*, November, 1928, V. 5, p. 437.)

Since 20th November, 1928, Königswusterhausen has sent out Fultograph picture broadcasting every day at fixed times (10.45 p.m. on Tuesdays and Fridays, other days at 1.45 p.m.). France will this winter begin broadcasting from Toulouse (on the Bélin system), during the intervals of an opera, the pictures of the various performers.

FORTSCHRITTE IN DER BILDTELEGRAPHIE (Advances in Picture Telegraphy).—F. Schröter. (*E.N.T.*, November, 1928, V. 5, pp. 449–458.)

From the Telefunken laboratories. Schriever's ring-shaped photoelectric cell is described. The cone-shaped ray, concentrating on a point of the picture, passes through the central space, so that the cell can be quite close to the picture and receives a large fraction of the diffused reflection. It has only two objections: loss of light by reflection, at the glass surface, of the obliquely-incident rays, and the difficulty and dearness in manufacture of the ring shape. The writer has invented a plan avoiding these difficulties, using a right-angled prism to direct the ray on to the picture and a paraboloid reflector to collect the diffused light on to the ordinary type of cell; the rays thus collected cut through the glass wall of the cell at very favourable angles. The point next dealt with is the difficulty of perfect half-tone working, one requirement for which is a straight line characteristic for the receiving circuits. A special design of point-glow lamp is described and illustrated, which in the anode circuit of an amplifying valve gives a practically straight line characteristic; it also possesses many other desirable properties. Excellent examples of its work are shown. The rest of the paper is devoted to short wave facsimile telegraphy. Fruitless attempts to annul atmospheric disturbances by "compensation" circuits have now been replaced by the new principle of replacing a single signal impulse by an "impulse-statistic"; the method of spaced-repetition, invented by Verdan and applied (for ordinary telegraphy) in the Baudot-Verdan system (Abstracts, 1928, V. 5, p. 406) has been adapted by the writer to the subject in question. Fading is a serious trouble in short wave facsimile telegraphy, and although useful reduction of its effects has been attained by combined aerials, limitation of signals, and wave-changes ("wobbles"), much remains to be done against both fading and atmospherics. According to the writer's invention, the record (transmitting or receiving) is in the form of a narrow tape the moving path of which is so looped that at every sweep of the scanning point the latter passes across two or three widths of the tape side by side yet separated from each other, along the tape, by any desired distance. Thus the Verdan effect is produced; but for speeds of 500 wds./per min., involving a scanning-point velocity of 3.8 metres per sec., a further refinement has been introduced; the scanning point crosses the tape not at right angles to its length but at an angle of 5 deg. to 10 deg., so that any disturbance occurring during one sweep of the point is split up among several neighbouring letters. The combined process thus obtained is called the "slanting line-jump scanning."

THE SELENIUM CELL: ITS PROPERTIES AND APPLICATIONS.—G. P. Barnard. (*Journ. I.E.E.*, December, 1928, V. 67, pp. 97–120.)

Early history; the Construction of Selenium Cells (of various types); their Properties; Theories of the Action; Practical Applications (Photometry and Relay Problems; the Optophone—by which the blind can read ordinary print; the Photophone; Talking films; Television); and a bibliography mounting into hundreds.

CONTROLLING THE TELEVISION SCANNING DISK. (*Scientific American*, November, 1928, p. 458.)

Manual control of the motor by means of a continuously adjustable rheostat is here recommended, aided by an accelerator push-button to increase the speed momentarily when bringing the disc into synchronism. Alexanderson is quoted as saying, "with a little practice and co-ordination between the eye and the hand, it is possible to hold the picture in the field of vision as easily as one steers one's car down the middle of the road."

TELEVISION.—A. Dinsdale. (Review in *Electrician*, 21st December, 1928, V. 101, p. 705.)

From this review, it appears that the Baird system is chiefly dealt with, being described in probably greater detail than ever before; but information is also given of the methods of the Bell Laboratories, Jenkins, Alexanderson, Belin, Holweck, Mihaly, and Szczepanik. Dr. Fleming's "foreword" is here summarised, and various

criticisms are made of omissions in the book. It is compared with Dauvillier's account (Abstracts, 1928, V. 5, p. 291).

STANDARDISATION OF TELEVISION APPARATUS. (*Nature*, 1st December, 1928, V. 122, p. 853.)

In the U.S.A. it is officially recommended that forty-eight lines with fifteen separate pictures (frames) per second shall be standardised. *Nature* remarks that the pictures will not show much detail, being decidedly inferior in this respect to those of Baird.

RADIOVISION. (*Nature*, 24th November, 1928, V. 122, pp. 809–810.)

Correspondence on the use of the terms "radiovision" and "television."

THE DISTRIBUTION IN DIRECTION OF PHOTO-ELECTRONS FROM ALKALI METAL SURFACES: THE VOLTAGE-CURRENT RELATION IN CENTRAL CATHODE PHOTO-ELECTRIC CELLS.—H. E. Ives, A. R. Oplin and A. L. Johnsrud; T. C. Fry. (*Phys. Review*, June, 1928, V. 31, p. 1127.)

STUDIES IN FLUORESCENCE AND PHOTOSENSITISATION IN AQUEOUS SOLUTIONS.—W. West, R. H. Müller and E. Jette. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121A, pp. 294–317.)

MEASUREMENTS AND STANDARDS.

THE DEPENDENCE OF THE FREQUENCY OF QUARTZ PIEZO-ELECTRIC OSCILLATORS UPON CIRCUIT CONSTANTS.—E. M. Terry. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1486–1506.)

Author's summary and conclusions are as follows:—

The mathematical theory for the quartz piezo-electric stabilised, vacuum-tube-driven oscillator is given for the following cases: tuned plate circuit, inductance-loaded and resistance-loaded triode with the crystal between grid and plate, and also between grid and filament for each case. The condition for oscillations and the exact expression for the frequencies, damping factors, coupling coefficient, tube constants, etc., is given. In the analysis of the oscillator the equivalent network for the crystal given by Van Dyke has been used. The theory has been checked by measuring the variation in frequency of a quartz-stabilised oscillator for variations in impedance of the plate circuit, for the tuned circuit and resistance-loaded tube respectively. To satisfy the condition for oscillation it is necessary to use values for the equivalent resistance of the crystal somewhat smaller than those given by Van Dyke's formula. A discussion of the general method by which conditions for oscillation and expressions for the driven frequency of an oscillator may be obtained from the coefficients of differential equations up to the fourth order is included.

A quartz crystal oscillator, when used to stabilise a vacuum-tube-driven circuit, does not oscillate at a frequency determined by its elastic and piezo-electric properties alone, but becomes part of a coupled system, and the actual resultant frequency is influenced by the degree of coupling of the two systems and the values of the constants of the entire circuit, including those of the driving device in the case of continuous oscillations. In doubly periodic vacuum-tube-driven circuits, one of the normal modes of oscillations is excited when the crystal is connected between grid and plate, and the other when connected between grid and filament. Although the oscillations are more powerful when the frequency of the plate circuit is close to that of the crystal, the departures of the resultant frequency from the natural frequency of the crystal are greater. For purposes of accurate frequency standard maintenance, the resistance-loaded circuit is much to be preferred, and when a crystal has been standardised it must always be used in exactly the same circuit and under exactly the same conditions as when the standardisation was made. It is desirable from this standpoint to preserve not merely the crystal, but the entire circuit permanently assembled.

DEVELOPMENT OF FORMULÆ FOR THE CONSTANTS OF THE EQUIVALENT ELECTRICAL CIRCUIT OF A QUARTZ RESONATOR IN TERMS OF THE ELASTIC AND PIEZO-ELECTRIC CONSTANTS.—P. Vigoureux. (*Phil. Mag.*, December, 1928, V. 6, pp. 1140–1153.)

PIEZO-ELECTRIC OSCILLATOR CIRCUITS WITH FOUR-ELECTRODE TUBES.—J. R. Harrison. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1455–1470.)

The original Cady circuit has been superseded by the Pierce circuit because it cannot be used for crystal oscillations at the high-frequency modes, *i.e.*, the vibrations at the frequency determined by the thickness of the plate. The writer, however, finds that the Cady type of circuit can be directly applied to the screen-grid valve, and when thus applied can be used to advantage at the high-frequency modes of the crystal. Such a circuit, he says, has advantages over the Pierce type in more constant frequency and greater stability*; and (at the lower radio frequencies) greater power output; particularly at those lower frequencies for which flexural vibrations are employed; at 6,000 m., such a circuit gave an output more than twice that of a corresponding Pierce circuit. When thus oscillating the crystal shows a tendency to creep lengthways until a position is reached which gives maximum power output; if displaced from this position it will return to it again; this is not due either to air blasts or to a dielectric phenomenon, but to the vibration of the crystal against its support. Two of these circuits are described, and compared with Hull's recent four-electrode circuit. The occurrence of twin oscillation frequencies is discussed, and the difficulties in obtaining flexural vibrations with a three-electrode valve. In the subsequent discussion, there is an argument between the writer and A. Hund.

* *i.e.*, the power of starting oscillating without retuning.

Sur un Pendule Très Peu Amorti (A Very Lightly Damped Pendulum).—R. Planiol. (*Comptes Rendus*, 19th November, 1928, V. 187, pp. 933–935.)

A torsion pendulum, consisting of a brass cylinder 7 cm. in diameter and 8 cm. long suspended by a quartz fibre 25/100 mm. in diameter and 4.5 cm. long, was set twisting in a container exhausted by a Holweck molecular pump. The period of a complete oscillation was 10.942 sec. In 16 days the amplitude of the swing had decreased from a value 12.67 to 2.17. The damping due to the medium would appear to have been abolished, the only damping being due to the elastic hysteresis of the quartz and to the support. The energy lost during the period was 2×10^{-4} erg for the larger amplitudes and 10^{-6} erg for the smaller. The small damping suggests that the pendulum could be kept going by pressure of radiation; it would carry a mirror on to which a light ray, controlled by a photoelectric cell, would be directed. The comparison of a torsion pendulum of this type with a swinging pendulum similarly mounted would perhaps be useful in the study of the variations of gravity.

The Maintenance of Mechanical Oscillations by Magnetostriction.—J. H. Vincent. (*Electrician*, 28th December, 1928, V. 101, pp. 729–731.)

After a historical summary, the writer describes experiments on the longitudinal vibration of ferromagnetic bars under forces mainly due to magnetostriction; mild and cast steel bars could be maintained in resonant vibration with great ease; with nickel the effects were even more striking. With cast steel, frequencies up to 5,200 p.p.s. were obtained; with nickel, 19,900 has been reached and the experiments are being continued towards still higher frequencies. The paper is to be concluded in a later issue. (*Cf.* Pierce, Abstracts, 1928, V.5, p. 643.)

A System for Frequency Measurement Based on a Single Frequency.—Bureau of Standards Note. (*Journ. Franklin Inst.*, December, 1928, V. 206, p. 844.)

An accurate and rapid method of checking the frequencies of one piezo oscillator after another; the heterodyne note, produced by the oscillator under test and one set by the standard, is "matched" with a similar note from a calibrated audio-frequency generator.

A Tuning-fork Controlled Audio-Oscillator.—C. L. Lyons. (*Journ. Sci. Inst.*, November, 1928, V. 5, pp. 361–363.)

Description of an American hummer which the writer has found more satisfactory and reliable than any other kind he has tried. Its output is about 60 milliwatts at 1,000 p.p.s. By use of a tapped secondary output transformer, three different voltages may be obtained (0.5 to 5.0 V), but by making use of resonance voltages of 50 or 100 may be obtained if required. The input voltage is 4–8 V.

The Graphical Estimation of Low-frequency Choke Amplifier Performance.—W. A. Barclay. (*E.W. & W.E.*, December, 1928, V. 5, pp. 660–666.)

Sowerby (*ibid.*, April 1928) has utilised the plate voltage/plate current graph to derive the best values of resistance, etc., for given conditions of amplification by resistance amplifiers. A similar treatment of choke-coupled L.F. amplifiers is impossible owing to the increased number of variables, 3 instead of 1. Indirect methods are therefore necessary, and the present paper describes a simple graphical construction devised by the writer to avoid the prohibitive labour of arithmetical work involved in the usual methods. The construction results in the finding of the centre and dimensions of the ellipse for greatest signal strength which will represent without distortion at a given frequency the working locus of a given choke, using a given H.T. voltage. The centre when found indicates the necessary grid bias to apply for the distortionless amplification of signals of the given strength and frequency. The paper includes a statement of the problem, a mathematical analysis and a proof of the construction.

Quantitative Methods used in Tests of Broadcast Receiving Sets.—A. F. Van Dyck and E. T. Dickey. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1507–1531.)

Phrases, such as "one hundred times audibility," a "half-stage audio better" (than the standard set), "audible two rooms away," selectivity "sharp as a knife," or even "razor-edge," are quoted as representing the average receiving set test methods during the "first twenty-five years or so" of wireless. In 1922 the authors (aided later by W. Van B. Roberts) began to develop methods and equipment for quantitative measurement of receiving set performance. It was soon found that measurements of individual parts gave no true measurement of the whole, so that except for special purposes (*e.g.*, in locating the cause of inferior performance, or in developing a new set) the tests evolved and here described are for the overall performance of a complete set; they are so arranged that the test results can be used to predict how the set will perform under any specified service conditions. They can be divided into two classes: "special engineering" and "production" tests; the apparatus and methods for both are described. A new form of radio-frequency oscillator, designed for this work, is described; also shielded test booths for the work. The methods include the measurement of sensitivity, selectivity and "fidelity."

The Constant Impedance Method for Measuring Inductance of Choke Coils.—H. M. Turner. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1559–1569.)

The method described has been used to measure, at power frequencies, the inductance of iron-cored choke coils (of the type commonly used in wireless as filters) of values from one to more than 2,000 henrys. The writer says that he discovered in 1918 the unique property of parallel circuits on which the method is based, namely, that when an alter-

nating E.M.F. is impressed on a parallel circuit, a "critical condition" can be obtained (by a suitable choice of frequency, inductance and capacity) at which the supply current is absolutely independent of the resistance of the inductive branch, being equal to the current through the capacity branch. Under these conditions, a switch in the inductive branch can be opened and closed without altering (except momentarily) the reading of an ammeter in the supply circuit. The "critical frequency" is 0.707 times the resonant frequency for L and C in series; and when the standard variable condenser is adjusted so as to give this relation, L is calculated from $L = \frac{1}{2}\omega^2 C$. Two circuit arrangements are illustrated, each having its own advantages for certain cases. Several families of curves are given showing how the inductance depends on the magnitude of the superposed alternating and D.C. magnetomotive forces. The method can also be used at higher frequencies.

THE HIGH-FREQUENCY RESISTANCE OF TOROIDAL COILS.—S. Butterworth. (*E.W. & W.E.*, January, 1929, V. 6, pp. 13–16.)

It is pointed out that since a well-designed toroidal coil has more than twice the high-frequency resistance of a well-designed solenoidal coil of equal inductance, and since mutual interference can usually be avoided with the latter coils by suitable arrangement, toroidal coils should only be used when one cannot afford the slightest trace of electromagnetic interference. Formulæ and tables of constants are given for the resistance and inductance of these coils: methods of deriving the best diameter of wire and the best shape of toroid are shown.

SUPPLEMENTARY NOTE TO "ABBREVIATED METHOD FOR CALCULATING THE INDUCTANCE OF IRREGULAR PLANE POLYGONS OF ROUND WIRE."—V. I. Bashenoff. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1553–1558.)

Extension of a paper in the same journal, December, 1927, p. 1013.

SPULENBERECHNUNG (Coil Calculation). — O. Droysen. (*Zeitschr. f. Fernmeldetech.*, No. 6, 1928, V. 9, pp. 81–85.)

Coils for relays, telephones, etc., are usually reckoned from empirical curves and tables. Here the calculation is prosecuted purely by formulæ, with the advantage that the best winding for the apparatus in question can be obtained directly for various conditions of use.

THE VARIATION OF EFFECTIVE CAPACITY OF AN AIR CONDENSER DUE TO HUMIDITY AND PRESSURE CHANGES.—G. D. Rock. (*Phys. Review*, June, 1928, V. 31, p. 1129.)

A heterodyne method was used. No numerical results are given.

FURTHER NOTES ON THE CALIBRATION PERMANENCE AND OVERALL ACCURACY OF THE SERIES-GAP PRECISION VARIABLE AIR CONDENSER.—W. H. F. Griffiths. (*E.W. & W.E.*, January, 1929, V. 6, pp. 23–30.)

The first part of an article supplementing previous articles (*ibid.*, January, February and May, 1928). A new type of moving plate is described in which a number of completely insulated sections are employed. The completeness of the elimination of calibration inconstancy due to small rotation irregularities and to slight post-calibration twisting or tilting of plates, by the use of such multi-sectioned plates, is discussed.

THE TRANSMISSION UNIT AND ITS APPLICATION TO RADIO MEASUREMENTS. — J. F. Herd. (*E.W. & W.E.*, January, 1929, V. 6, pp. 17–22.)

The T.U. (transmission unit) is now standardised in Britain, America and elsewhere and is in regular use in telephonic practice. The writer shows how it would find useful application in wireless measurements: how, for example, T.U. boxes (attenuation boxes calibrated in T.U.) can be used to measure the gain of an amplifier: or to adjust the voltage injection in making field strength measurements.

THE APPLICATION OF VACUUM TUBES IN MEASURING SMALL ALTERNATING CURRENTS OF ANY FREQUENCY.—R. E. Martin. (*Phys. Review*, June, 1928, V. 31, pp. 1128–1129.)

Currents down to the limit of sensitivity of the moving coil galvanometer can be measured, irrespective of frequency, by a four-valve arrangement which delivers the current, rectified, to the galvanometer. The latter is calibrated by D.C.

THE ERRORS ASSOCIATED WITH HIGH RESISTANCES IN A.C. MEASUREMENTS.—R. Davis. (*Journ. Sci. Inst.*, November, 1928, V. 5, pp. 354–361.)

This final part of the paper mentioned in January Abstracts has two sections: the Determination of the Characteristics of a Unit, and Practical Considerations in the Designing of a Resistor for High Voltages, having a small Phase Angle at the low and high voltage ends.

SUBSIDIARY APPARATUS AND MATERIALS.

DREHZAHLREGELUNG VON GLEICHSTROMMOTOREN MIT ELEKTRONENRÖHREN (Speed Control of D.C. Motors by Valves).—E. Reimann. (Summary in *E.T.Z.*, 22nd November, 1928, p. 1719.)

Motors up to 100 kW. are governed by 2 or 3 amplifier valves combined with one or more power valves. A small D.C. generator is coupled to the motor and any variations in its voltage due to change of speed are impressed on the grid of the first valve: the voltage corresponding to the standard speed being counteracted by a fixed battery voltage. The field strength of the motor is varied by the output plate current. For motors of 100 kW. the regulating lag is from 0.5 to 1.5 sec., while the final variation in speed and the maximum relative phase-displacement are of the order of a few thousandths. The peak variations of speed may be 5 times the final.

KONSTANTHALTUNG DER DREHZAHL VON MASCHINEN FÜR SIGNALZWECKE (Constant Maintenance of the Speed of Machines for Signalling Purposes).—W. Dornig. (*E.T.Z.*, 22nd November, 1928, Vol. 47, pp. 1713–1715.)

A full description of a centrifugal governor

apparently corresponding with the patent dealt with in Abstracts, January, 1929. Three of the contact-springs there described are used, equally spaced round the rim of the disc: the contact-adjustments being slightly different for each. The contacts are connected to short circuit a field resistance, and thus control the mean value of the field current. A commutator-device on the disc axle rhythmically short-circuits the resistance hundreds of times per second, thus preventing any serious sparking at the governor-contacts (which remain clean after months of use). Constancy of speed within 0.1 per cent. can easily be obtained for voltage fluctuations from 170 to 250 V. for full load and no load. The gravity action on the spring is an important factor in the success of the device, as it ensures only one contact per revolution for each spring.

METALLISIERUNG VON PAPIER (The Coating of Paper with Metal).—M. U. Schoop. (*E.T.Z.*, 13th December, 1928, p. 1826.)

In Schoop's laboratory in Zurich successful results have been obtained in coating paper of any kind with thin, uniform and strongly attached coats of various metals, which in spite of their thinness (0.01—0.015 mm.) show metallic continuity. The process involves the projection of extraordinarily fine sputtering from the liquefied metal.

TRANSPARENT STEEL (*Scientific American*, November, 1928. p. 463.)

By Muller's process, steel can be made in sheets of a few millionths' of a millimetre thickness, and as transparent as glass. The sheets are produced mathematically exact and uniform as to thickness without tears or flaws; the steel retains its structure unchanged. A sheet transmits light, cathode, Roentgen and radioactive rays; it can be magnetised. Applications to telephones, microphones, loud speakers, etc., and in the laboratory, are suggested.

MAGNETIC PERMEABILITY OF IRON AND MAGNETITE IN HIGH FREQUENCY ALTERNATING FIELDS. —G. R. Wait. (*Phys. Review*, April, 1927, V. 29, pp. 566–578.)

The relative values of the permeability of cast-iron filings, iron wires, and iron powder, in H.F. (50–1,700 m. wavelength) magnetic fields were investigated. Results disagree with those of previous workers who found anomalous changes at certain frequencies; these are suggested to be due to errors whose nature is specified.

DIE KATHODENSTRAHL-OSZILLOGRAPHENRÖHRE DER WESTERN ELECTRIC (The Western Electric Company's Cathode Ray Oscillograph Tube). —(*E.T.Z.*, 29th November, 1928, p. 1752.)

A description, with general arrangement diagram, of the Type 224 tube; with oxide-coated hot cathode needing only 300 V high tension and therefore workable off a dry battery giving 1 milliampere. A life of 100 working hours is mentioned; the sensitivity is about 1 mm./volt. Type 224A has a filament taking up to 1.7A (at 6 V) but an improved Type 224B has just been produced which needs only 0.85 to 1.15A at the beginning of its life, later on requiring gradually increasing current. The smaller initial current leads to a longer life.

FORTSCHRITTE IM BAU VON MITTEL- UND HOCHFREQUENZMASCHINEN (Progress in the Construction of Medium and High Frequency Machines).—K. Schmidt. (*E.T.Z.*, 25th October, 1928, pp. 1565–1569.)

Present applications (valve transmitters, induction furnaces, etc.) are first described. The rest of the paper deals with the "S" type generating plants designed by the writer: 100 kW., 500 cycles, with the high overall efficiency of 84 per cent.; 2 kW., 8,000 cycles, overall efficiency 52 per cent. (generator alone 74 per cent.); 300 W., 6,000 cycles, overall efficiency about 45 per cent.; and an aircraft propeller-dynamo, weighing 9 kg., output 1 kW. ("of the size of a 500 W. D.C.generator."). Curves are given.

STATIONS, DESIGN AND OPERATION.

RADIO STATIONS OF THE WORLD ON FREQUENCIES ABOVE 1,500 KILOCYCLES.—(*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1575–1604.)

A list drawn up by the Federal Radio Commission, giving in most cases the call letters, location, frequency, "frequency channel" and name of owner of the various stations: amateurs, being licensed for bands of frequencies rather than specific channels, are not included.

ANALYSIS OF BROADCASTING STATION ALLOCATION. —J. H. Dellinger. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, pp. 1477–1485.)

An exposition of the new allocation announced by the Federal Radio Commission on 11th September, 1928. It was drawn up in compliance with the requirements (of the 1928 Amendment to the Radio Act) as to the equalisation of broadcasting facilities between the zones and states, and with the decision that no existing station should be abolished at the time of its inception. It is believed to provide the greatest aggregate of radio service possible under these two conditions. It provides a "definite, invariant basis" of station assignment for each zone and locality: it can be improved, wherever interference is found to exist in actual operation, by the reduction of power or the elimination of particular stations, without disturbing the allocation as a whole: it eliminates heterodyne interference on 80 per cent. of the listener's dial: it recognises the essentially different requirements of local, regional and distant service.

THE PROBLEM OF INTERNATIONAL DISTRIBUTION OF BROADCAST WAVELENGTHS: PROPOSALS OF THE POLISH BROADCASTING COMPANY.— W. S. Heller. (*E.W. & W.E.*, January, 1929, V. 6, pp. 3–8.)

The 1926 Geneva scheme was criticised by Lemoine (*ibid.*, July, 1928) who suggested modifications. The present paper (by the Technical Director of the Polish Company) criticises both the scheme and Lemoine's proposed modifications, and makes other proposals. There is an Editorial on the subject on pp. 1 and 2.

A Beam Wireless Development. (*Engineer*, 28th December, 1928, V. 146, p. 703.)

A paragraph on the latest developments in the Marconi-Mathieu Multiplex System tests between Bridgwater and Montreal (Abstracts, 1928, V. 5, p. 525). The working of the system in both directions simultaneously has now been accomplished.

New Broadcasting Transmitter for Service in Czecho-Slovakia. (*Electrician*, 28th December, 1928, V. 101, p. 752.)

A paragraph on the largest of the chain of five stations now being built. This station, shortly to be erected at Bratislava by the Marconi Company, will deliver 12 kW. to the aerial. Wavelength band is 200–545 m.

Some Remarks on Ultra Short Wave Broadcasting.—B. van der Pol. (*E.W. & W.E.*, January, 1929, V. 6, pp. 9–12.)

Report to the Technical Committee of the U. Internat. de Radiophonie. Deals first with Emission: the first requirement is constancy of frequency, not only from day to day, but also during modulation, *i.e.*, the absence of frequency-modulation: to be obtained by (*a*) piezo-electric quartz oscillators, if necessary temperature-controlled, and (*b*) complete elimination of reaction from the power stage on the "drive." Propagation is then dealt with: results of a continuous 24-hour emission from PCJJ (30.2 m.), based on hundreds of letters from all parts of the world, are plotted in separate graphs for Inner Europe, Outer Europe, India, S. Africa, etc., etc. The question of distortion is briefly treated, and tentative suggestions as to the advisable frequency gaps for such stations are made.

Änderung der russischen Rundfunkorganisation (Change in Broadcasting Organisation in Russia). (*E.N.T.*, November, 1928, V. 5, p. 426.)

It is announced that the Broadcasting Company "Radio Peredatscha" is being dissolved and the whole of Russian broadcasting taken over by the People's Commissariat for Posts and Telegraphs.

"World-broadcasting" for Germany. (*E.T.Z.*, 25th October, 1928, p. 1584.)

A paragraph concerning the opening, in February, 1929, of a German short-wave high-power broadcasting station. Another short-wave broadcasting station is mentioned, in San Lazara, Mexico, working on 44 m. and audible in Europe.

GENERAL PHYSICAL ARTICLES.

Electronic Waves and the Electron.—J. J. Thomson. (*Phil. Mag.*, December, 1928, V. 6, No. 40, pp. 1254–1281.)

The discovery by G. P. Thomson and by Davisson and Germer of electronic waves (Abstracts, 1928, pp. 526 and 230) implies that the electron must be something much more complex than the point charge of negative electricity which had previously been regarded as its adequate representation. In "Beyond the Electron" and in a paper (*Phil. Mag.*; No. 33, p. 191), the writer has suggested a constitution for the electron which would cause a moving electron to be accompanied by a train of waves. In the present paper he develops the consequences of this hypothesis and describes some experiments which he has made in connection with it. The electron is pictured as built up of a nucleus (which—like the old conception of the electron—is a charge of negative electricity concentrated in a small sphere) surrounded by a structure of much larger dimensions referred to as the "sphere" of the electron, made up of parts which under electric forces of very high frequencies are set in motion and produce effects of the same type as are produced by convective currents of electricity. These parts are taken as being represented by an equal number of positive and negative particles of different masses but with equal and opposite electric charges. After considering such an electron in the stationary condition, and comparing its vibrations with the vibrations of an ionized gas (where the convection currents balance the displacement ones so that there is no effective current, no magnetic force, no transference of energy and therefore no radiation), the writer deals with the electron in motion parallel to the axis of x with the uniform velocity u. He shows that its frequency when in motion is greater than when stationary $\left(p = p_0 k\right.$, where p_0 and p are the natural frequencies of the "sphere" when stationary and in motion respectively, and $\left.k = \frac{1}{\sqrt{1 - \frac{u^2}{c^2}}}\right)$, and that the expressions for the electric and magnetic force round it contain the factor $\cos p\left(t - \frac{ux}{c^2}\right)$: *which represents plane waves travelling in the direction of motion of the electron.* The phase velocity is c^2/u and thus depends only on the velocity of the electron, and not upon the density of the electric charges in its sphere. The wavelength λ of the waves is given by

$$\lambda = \frac{2\pi c^2}{pu}, \text{ or } \lambda u = \frac{2\pi c^2}{p_0}\sqrt{1 - \frac{u^2}{c^2}}$$

$\left[\text{not } \sqrt{\frac{1 - u^2}{c^2}} \text{ as printed on p. 1267}\right]$. This is precisely the relation found by G. P. Thomson in his experiments on the diffraction of electrons. The relation between group velocity U and phase velocity V is $U = \frac{c^2}{V}$: in the case under consideration, $V = \frac{c^2}{u}$, so that $U = u$, and the energy travels along with the electron. Thus the electronic waves according to this view are waves of electric and magnetic forces of diminishing amplitude, differing from electric waves through the normal ether not only in phase velocity but also in having the magnetic force smaller relatively to the electric. If the direction of the electronic waves is deflected, as in the diffraction experiments, the path of the electron will be bent; conversely, if the path of

the nucleus is changed by the action of applied forces on its charge, the path of the waves will be changed also. The electronic waves must be in a super-dispersive medium—*i.e.*, in the "sphere," so that the length of the train of these waves will be a guide to the diameter of the sphere. G. P. Thomson estimated the length of the train in his experiments as at least 5×10^{-8} cm., which at first sight indicates that the size of the sphere is large compared with an atom; and while further consideration allows it to be less than this, the writer thinks (from the result of experiments) that it must be at least comparable with atomic dimensions. As regards the dimensions of the nucleus, the old calculations are entirely changed: the two parts of the electron, the nucleus and the sphere, are each capable of vibration, and when the electron is in a steady state the vibrations of the two parts will be in resonance: the electron has thus, in addition to the steady electric field due to the negative charge on the nucleus, an oscillating field (due to the sphere) in which the energy remains constant since there is no radiation. Thus the total energy of the electron is the sum of the energies of these two fields. The usual estimate for the radius a is deduced on the assumption that the energy due to the charge on the nucleus, $e^2/2a$, accounts for the whole electron energy: if $e^2/2a$ represents but a part—possibly a small part—of the total energy, the corresponding value of a would be much larger. Moreover, from G. P. Thomson's measurements of the wavelengths of waves associated with electrons moving with known speed, it can be deduced that p_0 is about 1.1×10^{20}, and from this it is found that a must be of the order of 5×10^{-11} cm., instead of 1.4×10^{-13} cm. The paper concludes by describing experiments which were to decide whether the deflection of an electron by an electric force is due primarily to the deflection of the electronic waves or (as on the usual theory) to the action on the negative charge on the nucleus. If the former is the case, the harder gamma rays from radium *C* (some of which must have frequencies about 1.1×10^{20}) should also be deflected by an electric force. So far the experiments are inconclusive.

Eine Bemerkung zur Arbeit von E. Rupp (A Comment on the Work of E. Rupp).—S. J. Wawilow. (*Zeitschr. f. Phys.*, 19th April, 1928, V. 48, pp. 1–10.)

Referring to Rupp's displacement of the wavelength of light by passage through a Kerr cell (Abstracts, 1928, p. 587) which was interpreted as a modification of the light frequency of the impressed voltage, the writer points out that the shift of wavelength can be regarded as an experimental verification of the Doppler-Michelson principle.

Modulation of Light Waves by High Frequency Oscillations. — A. Bramley. (*Nature*, 1st December, 1928, V. 122, pp. 844–845.)

Rupp's results (Abstracts, 1928, p. 587) seemed to agree well with the supposition that the wave form of frequency ν could be represented by an infinite wave train which would be split up into three wave trains of frequency $\nu + T$, ν, and $\nu - T$, where T is the frequency of the H.F. oscillations. The writer's results on light from an iron arc, however, indicate that the modulations may depend on the form of the light impulse; two of the lines being shifted while the remaining eight remained unchanged. He suggests that the damping coefficients of the pulses corresponding to the shifted lines were related in a simple manner to the frequency of the oscillations present in the Kerr cell, and that for this reason the frequencies of these particular pulses were changed.

L'Effet Raman dans la Domaine des Rayons X. (The Raman effect in the region of X-rays).—M. Ponte and Y. Rocard. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 828–829.)

The writers point out that the phenomenon found by Davis and Mitchell—that the structure of an X-ray after diffusion by a body is more complex than the incident ray—is nothing more or less than the Raman effect applied to X-rays. Quantitatively, the results show that the Raman effect deserts more and more, as the frequency mounts, the classical theory, so that while in the low frequencies of wireless it conforms rigorously with the undulatory theory, in light it begins to demand quanta, and in X-rays it depends entirely on the quantum mechanics.

Sur les Moments Atomiques (Atomic Moments).—P. Weiss and G. Foëx. (*Comptes Rendus*, 29th October, 1928, V. 187, pp. 744–746.)

The writers give a table of the atomic moments (measured in magnetons) of a number of substances, with the names of the workers who measured them. Results whose accuracy is considered doubtful are excluded.

Evidence . . . as to the Ultimate Nature of Magnetism.—T. D. Yensen. (*Phys. Review*, July, 1928, V. 32, pp. 114–122.)

X-ray analysis of films of electrolytic iron in strong magnetic fields showed that even the most minute crystal aggregates were not oriented; thus lending support to the conclusion that the magneton is an atomic property.

Über Wiedervereinigung positiver Ionen mit freien Elektronen (Recombination of Positive Ions with free Electrons).—R. d'E. Atkinson. (*Zeitschr. f. Phys.*, 12th October, 1928, V. 51, pp. 188–203.)

The question is studied experimentally whether, at the passage of a beam of positive ions through an electron cloud, signs of recombination are produced in the form of loss of ions. The negative result establishes an upper limit for the probability of recombination.

Schwingende Kontinua mit willkürlich verteilter, kleiner Dämpfung (Oscillating Continua with arbitrarily distributed small Damping).—M. J. O. Strutt. (*Ann. d. Physik.*, 5th October, 1928, V. 87, No. 2, pp. 145–152.)

The mathematical treatment is finally applied to two examples—the case of an open aerial and the case of the acoustics of a room.

MISCELLANEOUS.

DIE FERNLENKVERSUCHE DER REICHSMARINE IN DEN JAHREN 1916-1918 (Distant Control Experiments in the German Navy, 1916-1918).—H. W. Birnbaum. (*Zeitschr. f. Hochf. Tech.*, November, 1928, V. 32, pp. 162–170.)

Completed in 1919, this paper could not be published till now. It is divided into two parts: the Work of the Test Commission (Communications) and the Tests of the Department for Torpedo Inspection (Kiel). The former deals with the work of Max Wien, Droysen and the writer on the ideas of Wirth, Röver-Mauracher and Siemens and Halske: the question of relays: jamming: tests at Hausneindorf (Autumn, 1914); tests on distant control of motor boats from a land station (Müggelsee, Winter, 1914-1915); from aeroplanes (Travemünde, Spring 1915). The latter part deals with the practical applications, in the war, of the above work in the hands of the writer, Pungs and Pirani; the Siemens system of indirect control by cable; direct wireless control without cable; note-tuned circuits; the aircraft transmitter; the directional effect (unwanted) of the aircraft transmitting aerial; range, and freedom from interference, of distant-controlled motorboats. The recently paragraphed tests on the wireless-controlled battleship "Zähringen" were based on the above work.

DIE PHYSIKERTAGUNG IM RAHMEN DER VERSAMMLUNG DEUTSCHER NATURFORSCHER UND ÄRZTE IN HAMBURG 1928 (Conference of Physicists at the German Association for Science and Medicine, Hamburg, 1928).—(*E.T.Z.*, 13th December, 1928, pp. 1814–1817.)

Short abstracts, by E. Lübcke, of 35 papers on electrical subjects.

WIE HOCH MUSS EINE SPANNUNG SEIN, UM DEM MENSCHEN GEFÄHRLICH ZU WERDEN? (How High must a Voltage be to be Dangerous to Life?)—H. F. Weber. (*Bull. d. l'Assoc. Suisse d. Élec.*, 5th November, 1928, pp. 703–706.)

A very full report, regarding A.C. only, made in 1897 to Brown Boveri & Cie, and now revived in view of the interest taken in the subject by the International Union of Producers and Distributors of Electrical Energy. One general conclusion can be mentioned—that any A.C. voltage over 100 v. is dangerous to life if there is any possibility of contact with both poles.

"THE TRANSMITTING STATION ACTUALLY SENDS OUT WAVES OF ONE DEFINITE FREQUENCY, BUT OF VARYING AMPLITUDE."—A. W. Ladner. (*E.W. & W.E.*, January, 1929, V. 6, p. 37.)

In this further contribution to the argument (started by an Editorial in *E.W. & W.E.* for August, 1928, under the above title) the writer begs the Technical Editor to give an illuminating treatment of "Suppressed carrier" working, on the single wave basis. His own version of such a treatment brings in as analogy the celebrated smile on the face of the Cheshire cat.

THE WASHINGTON INTERNATIONAL RADIOTELEGRAPHIC CONFERENCE OF 1927.—J. A. Slee. (*E.W. & W.E.*, Dec., 1928, pp. 666–668.)

The Chairman's Inaugural Address to the Wireless Section of the Institute of Electrical Engineers.

A DECIMAL CLASSIFICATION OF RADIO SUBJECTS: AN EXTENSION OF THE DEWEY SYSTEM.—(*Proc. Inst. Rad. Eng.*, October, 1928, V. 16, pp. 1423–1428.)

Circular 138, of the same title, was published by the Bureau of Standards, Washington, in 1923. The present article describes a proposed revision of this Circular.

THINGS WE DON'T THINK OF.—H. M. Hobart. (*G. E. Review*, October, 1928, V. 31, pp. 519–525.)

An unusual little address based on various actual occurrences where "things went wrong" owing to causes which should have been foretold by theory or by the proper correlation of already known facts.

CONTRACTIONS FOR TITLES OF PERIODICALS.—R. L. Sheppard. (*Nature*, 3rd November, 1928, V. 122, p. 685.)

A continuation of the argument referred to in Abstracts for October and December, 1928. The writer concludes by urging the soundness of the rule that abbreviated titles must be intelligible without a key.

SUR LES SPECTRES D'ÉTINCELLE DU SÉLÉNIUM ET DU TELLURE (Spark Spectra of Selenium and Tellurium).—L. and E. Bloch. (*Comptes Rendus*, 1st October, 1928, V. 187, pp. 562–564.)

The use of the "electrodeless discharge" has enabled the writers to separate out, in the spectrum of Tellurium, at least three successive degrees of excitation, probably corresponding to atoms singly, doubly, and trebly ionised. Sulphur showed only the two degrees of excitation already found by the writers *without* the use of the electrodeless discharge; but Selenium (which hitherto had given two degrees only) now showed a distinct third degree.

NOUVEAU SYSTÈME DE TÉLÉPHONIE OPTIQUE PAR LA LUMIÈRE VISIBLE OU ULTRAVIOLETTE (New System of Optical Telephony by Visible or Ultraviolet Light).—Q. Majorana. (*Atti. Congr. Intern. d. Fis. Como.*, 1927, V. 1, 1928, pp. 287–289.)

EINE OPTISCH-ELEKTRISCHE ZUGBEEINFLUSSUNG (An Optical-electrical System of Train Control).—Baeseler. (*E.T.Z.*, 6th December, 1928, pp. 1790–1792.)

The locomotive carries the light transmitter, giving pulses of light which pass vertically through about 3 metres of air and then (at appropriate

points on the track) encounter a track mirror and are reflected back to the locomotive on to a selenium cell with attached amplifier, etc. A special tachometer arrangement can be added which pulls up the train if the speed at a certain point is excessive. The apparatus works by day or night. It is being tested on a section of railway in Bavaria.

Sur la Résolution Complète du Problème de la Carte dans l'Espace (The Complete Solution of the Problem of Space Mapping).—H. Roussilhe. (*Comptes Rendus*, 26th November, 1928, V. 187, pp. 970–972.)

A method of obtaining the position of a point in space from which an aerial photograph is taken. The paper should be read in conjunction with others by the same writer (*ibid*, 1922 and 1928). When rapid orthochromatic plates can be obtained with grain 1/100 mm. instead of the present 1/20 mm., even greater accuracy will be possible.

Talking Films. No. 1.—The British Phototone System.—(*Wireless World*, 12th December, 1928, V. 23, pp. 793–794.)

Piezo-electric Generation of Mechanical Oscillations.—(*German Patent* 4,611,147, *Telefunken*, published 14th June, 1928.)

A piezo-crystal is so constructed or oriented, in an A.C. field, that an asymmetry is present: with the result that a torque is produced which can be used to drive a small motor or to release or re-set a relay.

Broadcasting Over the Supply Mains—Development in the U.S.A.—(*Electrician*, 7th December, 1928, V. 101, p. 665.)

A paragraph on a recent big business transaction "foreshadowing the lines on which broadcasting in the United States is expected to develop." The largest supplier of electric light and power in the U.S.A. (the North American Company) has granted the Kolster Radio Corporation title to 600 of its patents in return for exclusive licences in the field of wired radio to one of its subsidiaries, Wired Radio, Inc. A further clause deals with the manufacture of goods to an enormous estimated yearly value, for the latter company. The patents include the "fundamental patent" for chain broadcasting, as well as patents for television and talking motion pictures. It is predicted that within the coming decade or two "most of the broadcasting in the United States will be carried on over household electric light and power wires, the air being left clear for commercial and safety communications. In this way, according to wireless experts, the worst of the broadcasting difficulties with respect to interference will be overcome." *Cf.* O.F.B., January Abstracts.

Untersuchungen über die Elektrizitäts leitung durch sehr dünne Schichten fester Dielektrika (Investigation of the Conduction of Electricity through very thin Layers of Solid Dielectrics).—E. Espermüller. (*Arch. f. Elektrot.*, 1st November, 1928, V. 21, pp. 148–169.)

Co-existence of Power Lines and Communication Lines.—L. Selmo, E. Brylinski. (*Rev. Gen. d. l'Élec.*, 1st September, 1928, V. 24, pp. 303–306.)

On the General Characteristics of Induction. K. Kanaya. (*Researches of Electrot. Lab.*, Tokio, No. 231, June, 1928, 90 pp.)

A New Ultra-violet Lamp. (*Electrician*, 9th November, 1928, V. 101, p. 526.)

A paragraph on a new type of metallic vapour arc lamp in which the effect of these vapours is supplemented and modified by the presence of a mixture of permanent gases "having certain electrical and optical characteristics," and also by the presence of an incandescent solid body. The lamp requires no more manipulation during starting or running than an ordinary incandescent lamp.

Some Technical Uses of Ultra-violet Radiation.—L. V. Dodds. (*Elec. Review*, 2nd November, 1928, V. 103, pp 746.–747.)

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial.

Does a Vibrating Diaphragm Carry a Mass of Air With It?

In calculations concerned with vibrating diaphragms such as those of loud speakers, an addition is usually made to the actual mass of the diaphragm to allow for the mass of the air which is moved with the diaphragm. The effective mass of the vibrating diaphragm which must be used in calculating resonant frequencies is thus greater than its actual mass. At first sight this seems obvious, but on second sight it becomes less obvious, and a close examination of the subject shows it to be a more interesting phenomenon than one might have anticipated. If one considers the case of a disc fastened to the end of a rod, which is then moved rapidly backward and forward, like the piston of an engine in the absence of the cylinder, it is natural to assume that it will carry some air with it and thus increase its effective mass, but will this still be the case if the disc or piston vibrates in a cylinder into which it fits? Or again, if we consider an ideal acoustic oscillator in the form of a spherical balloon which is caused to swell and contract in rapid succession, say, by connecting it to a reciprocating air pump without the usual non-return valve, can we regard the spherical surface as carrying a mass of air with it, on its outward and inward movements, and if so, how much? It was the consideration of this problem of the pulsating sphere that suggested this editorial note, for it is a fact that a certain mass must be added to the actual mass of the spherical diaphragm to obtain the total effective mass in calculating the forces and resonant frequencies. One might be tempted to say that since the sphere cannot expand without pushing the air before it, it is obvious that some account of this must be taken in determining the total effective mass of the diaphragm. This argument is entirely countered, however, by the fact that in our example of the piston in a long cylinder no addition has to be made, although it certainly pushes the air before it when it moves.

Lord Raleigh's Investigations.

The pulsating sphere was studied by Lord Rayleigh; it lends itself to accurate and relatively simple mathematical treatment, and supplies the answer to our question. In a plane wave, such as that in a very long cylinder, the air particles are moving most rapidly at the moment of their maximum compression or rarefaction. If the wave were being produced in the cylinder by forcing a

piston to and fro, then if the piston itself had no mass, so that the forces acting on it were transmitted to the air, the force on the piston would be exactly in phase with its velocity. If the piston had a certain mass, then the total force would have to contain a component to overcome the inertia of the piston, and the velocity would now lag behind the applied force.

Divergent and Convergent Waves.

In the above we assumed a plane wave; if the sound wave is divergent then it is no longer strictly true that the velocity of an air particle reaches its maximum at the moment of maximum compression or rarefaction; the pressure and velocity are out of phase by an angle ϕ, where $\tan \phi = \lambda/2\pi R$, λ being the wavelength and R the distance from the centre from which the waves may be regarded as diverging. In a divergent wave the velocity of the air particles lags behind the pressure, whereas in a convergent wave the angle is given by the same formula, but the pressure lags behind the velocity. We are rarely concerned with the latter case and can limit our consideration to that of divergent sound waves.

Now the wave produced by any small area of the spherical surface will be a divergent beam and the pressure or force at the surface of the spherical diaphragm will therefore be out of phase with its velocity, just as if the diaphragm had a certain mass or as if a mass of air were attached to it. This mass is given by the formula

$$M = \frac{4\pi R^3 \rho}{1 + \left(\frac{2\pi R}{\lambda}\right)^2}$$

where ρ is the density of the air or other medium. When R is small compared with λ, this reduces to $M = 4\pi R^3 \rho$, which is three times the mass of the sphere if filled with air. The volume of air apparently moved with each square centimetre of the spherical surface is $\frac{R}{1 + \left(\frac{2\pi R}{\lambda}\right)^2}$, which decreases as R increases.

We thus see that the apparent attachment of a quantity of air to the diaphragm is a convenient fiction which is only necessary in the case of divergent sound waves, because such waves cause a phase displacement between pressure and velocity which can be simulated by an increase of the mass of the diaphragm.

G. W. O. H.

OBITUARY.

We publish in this number an article entitled "Output Characteristics of Thermionic Amplifiers." It is with very great regret that we have to announce that the author, Mr. B. C. Brain, B.Sc., has recently died of pneumonia after a short illness.

Mr. Brain, who had recently married, was a young man at the beginning of what promised to be a highly successful career. He was a member of the research staff of the British Thomson-Houston Company's works at Rugby, and a perusal of the article in this number will show with what ability and originality he handled the problems arising in the proper design of thermionic amplifiers. In publishing this article, we wish to extend our sympathy to his wife and to the other members of his family.

Output Characteristics of Thermionic Amplifiers.

By B. C. Brain, B.Sc. (Hons.), Engineering Laboratory, B.T.H. Co.

SUMMARY.—The improvements which have taken place in recent years in loud speaker design and the rapidly growing number of the radio public who desire a receiver giving faithful reproduction have resulted in the development of special large output power valves. For the design of these and their correct use, a knowledge of the factors which determine the output of a valve is essential.

The method that is commonly used at present is due to Warner and Loughren* and has been further dealt with by Green.† This method consists in drawing a series of plate voltage-plate current curves for various grid voltages and super-imposing upon these curves the load characteristic in such a way as to show the current and voltage at any instant. While it is probably true that this method will remain the most accurate means of determining the output of a valve, it has the disadvantage of requiring a considerable time to take the readings and plot the curves; also in some cases information may be required as to the capabilities of a valve before samples are available to hand.

It was with a view to overcoming these difficulties that the writer took up this investigation. It will be shown that all the data required to fix the operating conditions of a valve for maximum undistorted output can be obtained (by the aid of a slide rule and five minutes' work) from a knowledge of two valve constants. These constants are embodied in the information which usually accompanies commercially made valves.

A list of the symbols employed is given at the end of the article.

It is assumed that the reader is familiar with the general effect of a resistance load on the characteristics of a valve, which is dealt with in detail in the papers mentioned above.

Determination of the Optimum Load Resistance for Maximum Output.

IT has been shown graphically by Brown and other workers that the best load resistance is twice the A.C. resistance of the valve on the assumption that the plate volts/plate current characteristics are straight over the working range. This is a condition rarely obtained in practice, and we shall, therefore, deduce a perfectly general solution which holds whatever the shape of the plate voltage/plate current curves provided the plate current is sinusoidal.

Consider the elementary circuit in Fig. 1 (a).

A thermionic amplifier (which is drawn as a triode but which can equally well be a tetrode or pentode) has a purely resistive load R_x connected in its anode circuit. The anode current is supplied by a battery or other source having a negligible internal resistance and of voltage V_0.

The relation between the grid potential and the anode current is shown in Fig. 1 (b).

We shall suppose that the grid voltage is zero when the maximum current is flowing (*i.e.*, the grid is never positive), and that when the grid is most negative a small anode current still flows. These conditions are imposed to limit distortion.

When a signal voltage of constant frequency is applied to the grid the anode current will vary according to the curve in Fig. 1 (c).

Since the A.C. component of current in the anode circuit is assumed to be sinusoidal, the A.C. power dissipated in R_x will be proportional to

$$(I_{max.} - I_{min.})^2 R_x$$

$I_{max.}$ and $I_{min.}$ being the upper and lower limits of anode current respectively.

Let us assume that $I_{min.}$ is very small and is proportional to $I_{max.}$ Then the A.C. power is proportional to

$$I_{max.}{}^2 R_x.$$

Let us now consider the conditions *at zero bias* when

$$I_{max.} = (I_a)_{Eg=0}$$

and the anode voltage is

$$(V_a)_{E_g=0}.$$

For convenience in writing the subscript indicating $E_g = 0$ is omitted in the following work.

Applying Kirchhoff's law to the anode

* *Proceedings of the Institute of Radio Engineers*, December, 1926, p. 735.
† *E.W. & W.E.*, July, 1926, p. 402.

circuit

$$V_a - V_0 + R_x I_a = 0 \qquad .. \qquad (1)$$

or

$$\frac{V_a}{I_a} + R_x = \frac{V_0}{I_a}$$

V_a/I_a is the D.C. resistance of the valve (at $E_g = 0$) which we can call R, hence

$$I_a = \frac{V_0}{R + R_x} \qquad .. \qquad .. \qquad (2)$$

For the A.C. power in the load to be a maximum or minimum R_x is given by

$$\frac{d}{dR_x}(I_a^2 R_x) = 0 \qquad .. \qquad .. \qquad (2a)$$

or

$$I_a + 2R_x \frac{dI_a}{dR_x} = 0 \qquad .. \qquad .. \qquad (3)$$

In order to find $\frac{dI_a}{dR_x}$ differentiate (2) with

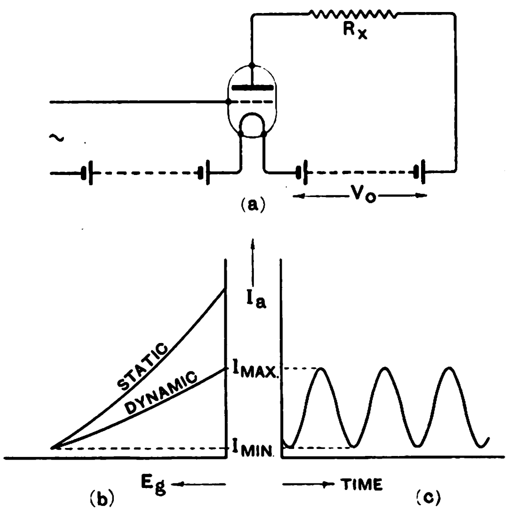


Fig. 1.

respect to R_x (I_a and R will both vary if the load resistance is varied)

$$\frac{dI_a}{dR_x} = -\frac{V_0}{(R + R_x)^2}\left(1 + \frac{dR}{dR_x}\right) \qquad .. \qquad (4)$$

Eliminating I_a and $\frac{dI_a}{dR_x}$ between (4), (2) and (3) we have

$$\frac{V_0}{R + R_x} - \frac{2R_x V_0}{(R + R_x)^2} \cdot \left(1 + \frac{dR}{dR_x}\right) = 0$$

or

$$R_x = \frac{R}{1 + 2\frac{dR}{dR_x}} \qquad .. \qquad .. \qquad (5)$$

This result is of interest. If the valve obeys Ohm's Law, *i.e.*, R = constant, $dR/dR_x = 0$ and $R_x = R$. This is the well-known result for a battery or generator having an ohmic internal resistance R, the power in the circuit being a maximum when the external resistance is equal to the internal resistance of the battery.

A condition we have not yet made use of is

$$V_a = f(I_a) \qquad .. \qquad .. \qquad (6)$$

which we can refer to as the law of the valve.

Hence $$R = \frac{V_a}{I_a} = \frac{f(I_a)}{I_a} \qquad .. \qquad .. \qquad (7)$$

We now have four variables, R, R_x, V_a and I_a, connected by the three equations, (1), (6) and (7).

Hence R can be expressed as a function of R_x, and therefore these equations are sufficient to give us both R and $\frac{dR}{dR_x}$ in terms of R_x.

Differentiate (7) with respect to R_x

$$\frac{dR}{dR_x} = \frac{f'(I_a)}{I_a}\frac{dI_a}{dR_x} - \frac{f(I_a)}{I_a^2}\frac{dI_a}{dR_x}$$

$$= \frac{f'(I_a) - R}{I_a} \cdot \frac{dI_a}{dR_x} \qquad .. \qquad .. \qquad (8)$$

$$\left(f'(I_a) \text{ denotes } \frac{d}{dI_a}f(I_a)\right)$$

re-writing equation (1) thus

$$f(I_a) - V_0 + R_x I_a = 0$$

and differentiating with respect to R_x

$$f'(I_a)\frac{dI_a}{dR_x} + R_x \frac{dI_a}{dR_x} + I_a = 0$$

or

$$\frac{dI_a}{dR_x} = -\frac{I_a}{R_x + f'(I_a)} \qquad .. \qquad (9)$$

putting this value in (8) we have

$$\frac{dR}{dR_x} = -\frac{f'(I_a) - R}{R_x + f'(I_a)}$$

but $f'(I_a) = \frac{d}{dI_a}f(I_a) = \frac{d}{dI_a}(V_a) = R_a$.

This is the differential or A.C. resistance of the valve under the operating conditions we are considering.

Hence $$\frac{dR}{dR_x} = \frac{R - R_a}{R_x + R_a} \qquad .. \qquad (10)$$

eliminating $\frac{dR}{dR_x}$ between (5) and (10) we get

$$R_x = \frac{R}{1 + 2\frac{R - R_a}{R_x + R_a}}$$

$$R_x^2 + R_x(R - R_a) - RR_a = 0$$

hence $R_x = R_a$ *or* $- R$ .. .. (11)

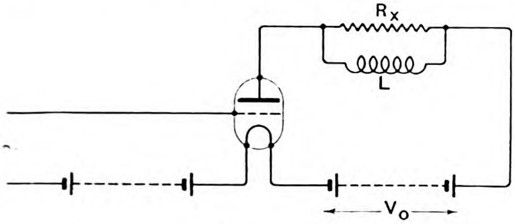


Fig. 2.

It is clear that maximum power is given by

$$R_x = R_a.$$

Thus when a resistive load is connected directly in the anode circuit of a valve as in Fig. 1 (a) the maximum power is developed in the resistance when its value is equal to the A.C. resistance of the valve *when the anode current is at its peak value.* We shall consider the significance of the clause in italics later.

The circuit shown in Fig. 1 (a) is rarely used because of the power wasted in the load resistance, owing to the D.C. component of anode current passing through it. The common arrangement is to use either a choke and condenser, or a transformer, to couple the valve to its load. Both these methods theoretically reduce to the circuit of Fig. 2. The choke L is supposed to have infinite inductance and negligible ohmic resistance, so that R_x only carries the sinusoidal output current while the steady anode current I_0 of the valve at its working bias (*i.e.*, without a signal input) flows through the choke. When a signal voltage is injected in the grid circuit A.C. power will be dissipated in R_x, while the steady current I_0 through the choke L is unaltered.

The equations we obtained in the previous case are now as follows:

Kirchhoff $V_a - V_0 + R_x(I_a - I_0) = 0$ (12)

Valve Law $V = f(I_a)$.

Condition for Max. Power

$$\frac{d}{dR_x}(I_{max.} - I_0)^2 R_x = 0 \quad .. \quad (13)$$

Since the current through R_x is assumed sinusoidal and $I_{min.}$ is very small and considered proportional to $I_{max.}$, we have

$$2I_0 = I_{max.} - I_{min.}$$

and $(I_{max.} - I_0) = pI_{max.}$ .. (14)

where $p = \frac{1}{2}\left(1 + \frac{I_{min.}}{I_{max.}}\right) =$ a constant.

Let us consider the conditions holding at the peak of the anode current swing, when the grid potential is zero. I_a and V_a will then be the instantaneous values of anode current and voltage at this point.

Combining (12) and (14), and (14) and (13) we get

$$V_a - V_0 + I_a pR_x = 0 \quad .. \quad (15)$$

$$p\frac{d}{dR_x}(I_a^2 . pR_x) = 0 \quad .. \quad (16)$$

These equations are thus identical with (1) and (2*a*) obtained for the circuit of Fig. 1 (a), except that R_x is now replaced by pR_x. Thus by proceeding in exactly the same way as before we obtain for the circuit of Fig. 2.

$$\text{Optimum } R_x = \left(\frac{R_a}{p}\right)_{I_a = I_{max.}}$$

or $$-\left(\frac{R}{p}\right)_{I_a = I_{max.}} \quad .. \quad (17)$$

If we assume that $I_{min.}$ is negligible compared with $I_{max.}$ then $p = \frac{1}{2}$. Hence we obtain the following important result for choke or transformer coupled loads in thermionic amplifiers.

To obtain the maximum power output from a thermionic amplifier the load resistance should be twice the value of A.C. resistance of the amplifier when the anode current is at its peak value.

The assumption made by previous writers that the anode volts/anode current curves are straight and parallel means that the A.C. resistance of the triode is a constant and therefore they have not specified the conditions under which the R_a of the valve is to be measured. The result is that the practice has become common of making the load resistance equal to twice the A.C.

resistance of the triode at the working bias. It will be seen later that the error introduced by using this value is small in the case of triodes.

In the case of pentodes, however, the error is serious. The A.C. resistance of these under working conditions (and as published by manufacturers) is of the order of 50,000 ohms, but with the optimum load in circuit the A.C. resistance at the peak of the anode current swing is about 4,000 ohms.

Certain writers dealing with the design of loud speakers for use with pentodes have assumed that the A.C. resistance of the valve was 50,000 ohms for the purpose of their calculations and it seems to the writer that this assumption is open to criticism, and that in fact 4,000 ohms should be taken as the effective resistance. On this basis the optimum load resistance should be about 8,000 ohms and this has been verified by experiment. The writer hopes to deal with this branch of the subject in a later paper. For the present, attention will be given to the problem of calculating the optimum load resistance, etc., for triodes.

The R_a of the valve when $I_a = I_{\max.}$ is impossible to determine without first knowing the load resistance, so that for equation (17) to be of any value to us we must translate

$$(R_a)^{I_a = I_{\max.}}$$

into terms of some value which is easily found and which is independent of the value of R_x. The most convenient conditions are those when $I_a = I_0$. It is easily seen from equation (12) that the anode voltage at this point is equal to the voltage V_0 of the battery, and that the anode current is independent of R_x.

Let us assume that the performance of a triode is represented by the equation:

$$I_a = k\left(\frac{V_a}{m} - E_g\right)^{\frac{3}{2}} \quad .. \quad (18)$$

where E_g is the *negative* voltage on the grid of the valve.

" m " is the amplification factor and " k " is a constant which can be calculated given any set of simultaneous values of V_a, I_a, and E_g. Thus " k " can be calculated from values taken at a single point on the I_a/E_g characteristic which most makers supply with the valve.

No correction will be made here for the variation in potential along the length of the filament which is known to modify the form of equation (18). The error which is usually small will be compensated for later. The argument for the present, therefore, only applies to valves with equipotential cathodes, such as the indirectly A.C. heated type.

By differentiating (18) with respect to V_a we get

$$\frac{dI_a}{dV_a} = \frac{3}{2}\frac{k}{m}\left(\frac{V_a}{m} - E_g\right)^{\frac{1}{2}}$$

hence the A.C. resistance of the triode is given by

$$R_a = \frac{dV_a}{dI_a} = \frac{2}{3}\frac{m}{k}\left(\frac{V_a}{m} - E_g\right)^{-\frac{1}{2}} \quad (19)$$

When the anode current is at its maximum value, $E_g = 0$ and $I_a = I_{\max.}$, and the anode voltage and A.C. resistance have their minimum values $V_{\min.}$ and $R_{\min.}$ respectively. Then from (18)

$$I_{\max.} = k\left(\frac{V_{\min.}}{m}\right)^{\frac{3}{2}} \quad .. \quad (20)$$

from (19)

$$R_{\min.} = \frac{2}{3}\frac{m}{k}\left(\frac{V_{\min.}}{m}\right)^{-\frac{1}{2}} \quad .. \quad (21)$$

from (12)

$$V_{\min.} - V_0 + R_x(I_{\max.} - I_0) = 0 \quad .. \quad (22)$$

When the anode current is at its steady value let

$$E_g = E_0,\ I_a = I_0,\ V_a = V_0,\ R_a = R_0$$

then from (18)

$$I_0 = k\left(\frac{V_0}{m} - E_0\right)^{\frac{3}{2}} \quad .. \quad (23)$$

from (19)

$$R_0 = \frac{2}{3}\frac{m}{k}\left(\frac{V_0}{m} - E_0\right)^{-\frac{1}{2}} \quad .. \quad (24)$$

when the grid is most negative $E_g = 2E_0$ and we have assumed that $I_a = I_{\min.} = 0$; also $V_a = V_{\max.}$

Then from (18)

$$I_{\min.} = 0 = k\left(\frac{V_{\max.}}{m} - 2E_0\right)^{\frac{3}{2}}$$

or

$$V_{\max.} = 2mE_0 \quad .. \quad .. \quad (25)$$

from (12)

$$V_{\max.} - V_0 + R_x(0 - I_0) = 0 \quad .. \quad (26)$$

Having obtained these important relations, we can return to the problem of finding $R_{\min.}$ in terms of R_0. We require this relation to interpret equation (17).

Since $I_{\text{min.}} = 0$ we have from equation (14)

$$I_{\text{max.}} = 2I_0$$

hence from (20) and (23)

$$\left(\frac{V_{\text{min.}}}{m}\right)^{\frac{3}{2}} = 2\left(\frac{V_0}{m} - E_0\right)^{\frac{3}{2}} \quad .. \quad (27)$$

but from (21) and (24)

$$R_{\text{min.}} = R_0 \frac{\left(\frac{V_0}{m} - E_0\right)^{\frac{1}{2}}}{\left(\frac{V_{\text{min.}}}{m}\right)^{\frac{1}{2}}}$$

hence from (27)

$$R_{\text{min.}} = \frac{1}{\sqrt[3]{2}} R_0 \quad .. \quad (28)$$

Returning to equation (17) we find that this gives

$$R_x = \left(\frac{2}{\sqrt[3]{2}}\right) R_0 \quad .. \quad .. \quad (29)$$

Hence maximum power output from a triode with a resistive load (transformer or choke coupled to the anode circuit) is obtained by making the Load Resistance approximately 1.6 times the A.C. resistance of the valve at the working bias.

Calculation of Working Bias, Load Resistance, etc., in Terms of the Valve Constants.

It frequently happens that the mean anode current I_0 which flows when a valve is put in a circuit having the optimum load resistance is greater than the makers recommend. This anode current limitation is imposed in order to ensure that the power dissipated at the anode (and consequently the temperature of the anode) shall be kept within safe limits. In order to meet this further consideration the load resistance may have to be much greater than the optimum value.

The first problem is to find how n, the ratio of the external resistance to the A.C. resistance of the valve, is related to E_0.

From equations (25) and (26), eliminating $V_{\text{max.}}$ and putting $R_x = nR_0$

$$V_0 + nR_0 I_0 = 2mE_0$$

Putting the values of R_0 and I_0 from (23) and (24) in this equation

$$V_0 + nk\left(\frac{V_0}{m} - E_0\right)^{\frac{3}{2}} \frac{2}{3}\frac{m}{k}\left(\frac{V_0}{m} - E_0\right)^{-\frac{1}{2}} = 2mE_0$$

whence
$$n = \frac{3V_0 - 6mE_0}{2mE_0 - 2V_0} \quad .. \quad .. \quad (30)$$

If we are given the safe limit of anode current at a battery voltage of V_0 we can calculate from (23) the value of E_0 which will just give this current. Putting in the value of E_0 in (29) we obtain the required ratio n.

We now have sufficient data to calculate all the required operating conditions to fit any circumstances, from the constants of the valve.

The method will be demonstrated on the

TABLE I.

$\frac{R_x}{R_0} = n$	Bias E_0	Anode Current I_0	Load Resis. R_x	Max. Current $I_{\text{max.}}$	Max. Plate Volts $V_{\text{max.}}$	Min. Plate Volts $V_{\text{min.}}$	**Output W.**
0.5	0.572	0.274	0.508	0.697	1.14	0.786	**0.0308**
1.0	0.625	0.230	1.09	0.538	1.25	0.662	**0.0394**
1.5	0.667	0.192	1.73	0.439	1.33	0.578	**0.0415**
2.0	0.700	0.164	2.43	0.368	1.40	0.511	**0.0406**
2.5	0.727	0.143	3.19	0.314	1.45	0.462	**0.0393**
3.0	0.750	0.125	4.00	0.269	1.50	0.418	**0.0365**
4.0	0.786	0.099	5.76	0.209	1.57	0.353	**0.0317**
5.0	0.813	0.081	7.70	0.171	1.63	0.308	**0.0282**
7.0	0.850	0.058	12.04	0.120	1.70	0.244	**0.0218**
10.0	0.885	0.039	19.60	0.080	1.77	0.185	**0.0155**
Symbol of Factor	B	A	C	D	—	F	H
	$B \cdot \frac{V_0}{m}$	$A \cdot k\left(\frac{V_0}{m}\right)^{\frac{3}{2}}$	$C \cdot \frac{m}{k}\left(\frac{V_0}{m}\right)^{-\frac{1}{2}}$	$D \cdot K\left(\frac{V_0}{m}\right)^{\frac{3}{2}}$	$2B \cdot V_0$	$F \cdot V_0$	$H \cdot Km\left(\frac{V_0}{m}\right)^{\frac{5}{2}}$

assumption that

$$R_x/R_0 = n = 3.$$

From (30)

$$E_g = \frac{3}{4}\frac{V_0}{m},$$

from (23)

$$I_0 = k\left(\frac{V_0}{m} - \frac{3}{4}\frac{V_0}{m}\right)^{\frac{3}{2}} = 1/8\ k\left(\frac{V_0}{m}\right)^{\frac{3}{2}},$$

from (24)

$$R_0 = \frac{2}{3}\frac{m}{k}\left(\frac{V_0}{m} - \frac{3}{4}\frac{V_0}{m}\right)^{-\frac{1}{2}} = \frac{4}{3}\frac{m}{k}\left(\frac{V_0}{m}\right)^{-\frac{1}{2}}.$$

Putting these values in (22) and solving the resultant cubic for $V_{\text{min.}}$ we get

$$V_{\text{min.}} = .418\ V_0,$$

hence from (20)

$$I_{\text{max.}} = k\left(\frac{.418V_0}{m}\right)^{\frac{3}{2}} = .27\ k\left(\frac{V_0}{m}\right)^{\frac{3}{2}}$$

The power output is

$$1/8\ I_{\text{max.}}^2 R_x = 1/8\left[.27\ k\left(\frac{V_0}{m}\right)^{\frac{3}{2}}\right]^2 4\frac{m}{k}\left(\frac{V_0}{m}\right)^{-\frac{1}{2}}$$

$$= .0365\ km\left(\frac{V_0}{m}\right)^{\frac{5}{2}}$$

It will be observed that each of the quantities involves some or all of the factors m, k and V_0, and has a numerical coefficient which is clearly a function of n only. Thus as different values of n are used the value of $V_{\text{min.}}$, say, will always contain V_0, but the numerical coefficient will alter.

The results of giving n various values between 0 and 10 is shown in Table I.

The numbers tabulated are the numerical coefficients, and the whole of the expression is given at the bottom of each column. The capital letters A, B, C, D, etc., called "symbol of factor," are given to facilitate reference to the curve of Fig. 3.

All the important variables are here plotted against n. Once n is fixed, a vertical line drawn through this value gives all the coefficients A, B, C, D, etc., simultaneously. Alternatively, if n is unknown but one of the other variables, say, $V_{\text{min.}}$, is fixed, we write

$$V_{\text{min.}} = F.V_0$$

from which the value of the numerical coefficient F is found. A vertical line through this value of F on the curve gives n and all the coefficients simultaneously.

The results given in Table I are for valves with equipotential cathodes. We shall now consider how these results can be modified to apply to valves having filaments directly heated by A.C. or D.C.* Owing to the

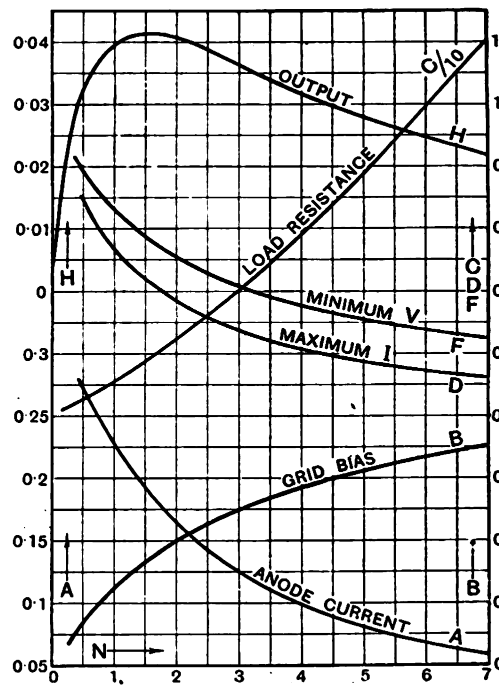


Fig. 3.

voltage drop along the length of a filament on D.C., the differences of potential between grid and filament, and anode and filament, are different at different parts of the filament. It can be shown that the mean effect of the biassing voltage due to this cause over the length of the filament is approximately the same as a decrease in anode voltage mz,

where $$z = \frac{E_f}{2}\left(1 + \frac{1}{m}\right) \quad .. \quad .. \quad (31)$$

E_f is the filament voltage.

Thus a valve having a 6-volt filament and an m of 4 will behave in approximately the same way as a valve of identical construction, but with the filament at a uniform

* Note.—It should be understood that this correction is a refinement of the method, and for the majority of purposes is hardly necessary. It is important to use the correction only when $\frac{V_0}{m}$ is small and/or the greatest accuracy is desired.

potential, having its anode voltage reduced by 15 volts.

By introducing the correction into equation (18) we can obtain the constant k of the valve. Having made use of the curve of Fig. 3 in the manner already described to find the coefficients A, B, C, D, etc., we can calculate the corresponding values of anode current, bias, etc., for a D.C. heated filament by replacing V_0 wherever it appears by $(V_0 - mz)$.

When A.C. is used for heating the filament the grid circuit should be always returned to the centre tap on the filament transformer. It will be seen that with this arrangement, so far as anode current is concerned, the result will be the same as if the filament were at a uniform potential. However, grid current can flow when $E_g = 0$ because, although the mean potential of the filament is zero, parts of it are negative with respect to the grid. In order to eliminate grid current, therefore, we must supply an *additional* bias to the grid of

$$z' = \sqrt{2}\frac{E_f}{2} \qquad .. \quad (32)$$

where E_f is the R.M.S. filament voltage. The resulting characteristic is then the same as that of our ideal triode having its anode voltage reduced by m times *this additional* bias, *i.e.*, mz'.

To obtain the value of k, then, we apply no correction to the values of I_a, E_g and V_a measured with A.C. heated filaments, but in working out the operating conditions from the coefficients obtained from the curves of Fig. 3 we subtract the correction mz' from the value of V_0 wherever it appears.

The quantity E_0 calculated by this means is really the peak value of the signal voltage for maximum output, and differs from the grid bias by the quantity z'. To obtain the grid bias we must, therefore, add a voltage z' to the calculated E_0 for A.C. heated filaments.

The use of these corrections for A.C. and D.C. conditions appears at first sight complicated, but the following examples will show the ease of manipulation of the method.

Examples Showing Method of Calculating Operating Conditions.

A particular B.T.H. B.12 valve was found to have the following constants, taken with D.C. heating of the filament.

$$E_a = 375 \text{ volts}$$
$$E_g = 80 \text{ volts negative}$$
$$E_f = 7.5 \text{ volts}$$

Anode current $= 32\ mA$.

Amplification factor $m = 3.25$.

The correction for D.C. is thus

$$z = \frac{7.5}{2}\left(1 + \frac{1}{3.25}\right) = 4.9 \text{ volts,}$$

and for A.C. is

$$z' = \frac{\sqrt{2} \times 7.5}{2} = 5.3 \text{ volts;}$$

also from (18) applying the correction for D.C.

$$32 = K\left(\frac{375}{3.25} - 80 - 4.9\right)^{\frac{3}{2}}$$

whence $K = \dfrac{32}{164} = .195$ milliamps/volt$^{\frac{3}{2}}$.

Example 1.—To find the Output and Operating Conditions with a battery voltage $V_0 = 425$ volts and the anode dissipation limited to 12 watts.

(*a*) Suppose the filament is to be heated by A.C.; the steady anode current $I_0 = \dfrac{12}{425} \times 1000 = 28.3$ milliamps; but Table I gives $I_0 = A\,.\,K\left(\dfrac{V_0}{m}\right)^{\frac{3}{2}}$ for the ideal triode; on A.C. this becomes

$$I_0 = A\,.\,K\left(\frac{V_0}{m} - z'\right)^{\frac{3}{2}} = 274\,A,$$

hence $A = \dfrac{28.3}{274} = 0.103.$

Drawing a vertical line on the curves of Fig. 3 through the point on the anode current coefficient curve corresponding to $A = .103$ we get the following values:

$n = 3.75$, $B = .775$, $C = 5.3$, $D = .22$, $F = .37$, $H = .033$.

Then $E_0 = .775\left(\dfrac{425}{3.25} - 5.3\right) = 97$ volts,

and the grid bias for A.C. is $(E_0 + z')$ $= 102.3$ *volts.*

Optimum load resistance

$$R_x = 5.3\,\frac{3.25}{.195}\left(\frac{425}{3.25} - 5.3\right)^{-\frac{1}{2}} = 7.9$$

(and since k is in milliamps) $= 7{,}900$ *ohms*

$$I_{\text{max.}} = .22 \times .195\left(\frac{425}{3.25} - 5.3\right)^{\frac{3}{2}} = 60 \textit{ milliamps.}$$

$$V_{\text{min.}} = .37\,(425 - 3.25 \times 5.3) = 151 \textit{ volts.}$$

$$\textit{Maximum Output} = .033 \times 3.25 \times .195\left(\frac{425}{3.25} - 5.3\right)^{\frac{5}{2}} = 3.65 \textit{ watts.}$$

(*b*) Suppose the filament is to be heated on D.C. Proceeding as in (*a*) but replacing z' by $z = 4.9$ volts we get

$$I_0 = .195\left(\frac{425}{3.25} - 4.9\right)^{\frac{3}{2}} A = 275\, A,$$

hence $A = 0.103$,

which gives the same values for the coefficients as before.

Then,

$$E_0 = .775\left(\frac{425}{3.25} - 4.9\right) = 97.7 \text{ volts};$$

hence the grid bias on D.C. is 97.7 *volts.*

Similarly

Optimum load resistance	$= 7{,}900$ *ohms*
$I_{\text{max.}}$	$= 60.5$ *milliamps.*
$V_{\text{min.}}$	$= 151$ *volts*
Maximum output ..	$= 3.7$ *watts*

Example 2.—*To find the Maximum Output when the Anode Battery Voltage is limited to* 200 *volts.*

Since there is no limitation of anode current now, we can use the optimum value of load resistance, *i.e.*, $n = 1.6$. Drawing a vertical line on the curves through this point we get

$$A = .19,\ B = .67,\ C = 1.9,\ D = .43,$$
$$F = .56,\ H = .041.$$

For D.C. operation of filament

Anode current

$$I_0 = .19 \times .195\left(\frac{200}{3.25} - 4.9\right)^{\frac{3}{2}} = 15.7 \text{ mA.}$$

(negative) Grid Bias

$$E_0 = .67\left(\frac{200}{3.25} - 4.9\right) = 38 \text{ volts.}$$

Load Resistance

$$R_0 = 1.9\,\frac{3.25}{.195}\left(\frac{200}{3.25} - 4.9\right)^{-\frac{1}{2}} = 4{,}220 \text{ ohms.}$$

Power Output

$$= .041 \times 3.25 \times .195\left(\frac{200}{3.25} - 4.9\right)^{\frac{5}{2}} = .63 \text{ watt.}$$

Beside the value of this method as a simple means of determining the output conditions, we have discovered several interesting facts relating to the output of valves which are not obvious from graphical considerations.

(1) The maximum output from a valve is proportional to the 2.5 power of the anode voltage and to the constant K, defined previously.

(2) The output of valves of identical construction but with differing "*m*" values operating with the same anode voltage is inversely proportional to the 1.5 power of "*m*."

(3) The grid bias for maximum output is directly proportional to the anode voltage and inversely proportional to "*m*."

Throughout this work we have assumed that the valve follows the 3/2 power law. In order to get reliable results it is necessary to make sure that the valve under consideration is of sound design. For instance, a valve in which the filament projects above the grid so that a fraction of the electrons can reach the anode uncontrolled by the grid will have an unduly high value of K, and also, to avoid distortion due to the excessive curvature at the lower end of the characteristic, it will be necessary to make $I_{\text{min.}}$ fairly large; hence there may be a considerable discrepancy between the calculated results and those obtained in practice. In a paper by Hann, Sutherlin and Upp* it is pointed out that in valves with very open mesh grids a similar effect is produced, resulting in a lower undistorted output than would be expected from the constants. It is unlikely, however, that there are any commercial valves which show this failing to any marked extent.

List of symbols used in the preceding

* *Proc. Inst. Rad. Engineers*, April, 1928.

On the Capacity of Dry Electrolytic Condensers.

By Philip R. Coursey, B.Sc., M.I.E.E.

THE development of large capacity condensers of the so-called electrolytic type which has taken place recently for use primarily in conjunction with battery eliminator apparatus for supplying the filament circuit of the valves of a radio receiver from electric light mains has raised the question as to the meaning of the statements of capacity attached to such condensers. With the majority of ordinary condensers using solid dielectrics such, for example, as paper, mica, etc., the statement of the capacity presents usually no ambiguity, since the capacity of such condensers does not vary very sensibly with either the frequency of the supply current or with the method of measurement. With the " dry electrolytic " condensers the same statement is not always true and it appears that the effective capacity of these condensers varies to some extent with the method of measurement, just as it also must vary with the frequency at which such measurements are carried out.

In most cases it has become customary to quote the results of ballistic methods of measurements of the capacity of these condensers, such methods involving the use of some form of ballistic galvanometer through which a discharge from the condenser is passed, the condenser having first been charged up from a source of small voltage, and the galvanometer usually being heavily shunted to allow for the rather heavy discharge currents which may arise from condensers of large capacity. The results obtained from such measurements do not, however, always appear to be as consistent as might generally be wished for, while some doubt may also arise as to whether the effective capacity of such condensers under working conditions bears any definite relationship to the results of such measurements.

As is now generally well known, these " dry electrolytic " condensers possess the feature of having a very large capacity in a very limited space, a condenser of this type having a capacity of over a thousand microfarads usually occupying no more space than a normal paper condenser of 4 or 5 microfarads capacity.

An ordinary type of condenser consists of sheets of metal and of dielectric interleaved with each other, or of strips of materials wound or rolled up together—the latter method being used with the more flexible dielectrics, such as paper. With these condensers the dielectric is highly insulating and the capacity of the condenser is determined by the area of the metal electrodes, the thickness of the dielectric separating them, and its dielectric constant. Liquid electrolytic condensers have been known for a long time in which the capacity effect was obtained by a chemically produced insulating film formed on the surface of a metal electrode immersed in an electrolyte. Aluminium plates readily form such films when placed in a solution of borax, or of ammonium borate or of similar materials, the action of a current flowing through such an electrolyte being to form a film of aluminium oxide on the surface of the metal. This film is very thin so that a large capacity can be obtained with metal plates of comparatively limited dimensions. The solution being electrically conducting serves in effect to bring the current flow from one metal electrode up to the surface of the insulating film formed on the other—so that the film becomes bounded on both sides by conducting materials.

In the recently produced so-called " dry-electrolytic " condensers a very similar arrangement is used, except that the large bulk of liquid electrolyte is dispensed with and replaced by a very limited amount of semi-fluid, but electrically conducting material kept in contact with the metal plate carrying the insulating film by means of a porous support which also holds the two metal plates apart. This porous support is commonly in the form of a layer of cloth or paper separating two strips of aluminium foil which form the main electrodes of the condenser, and on one of which the insulating film is formed.

In practice many different modes of constructing such condensers are used, but the results achieved with all are very similar. The electrolytic materials used differ as do also the precise forms in which they are used, but in all the real dielectric in the

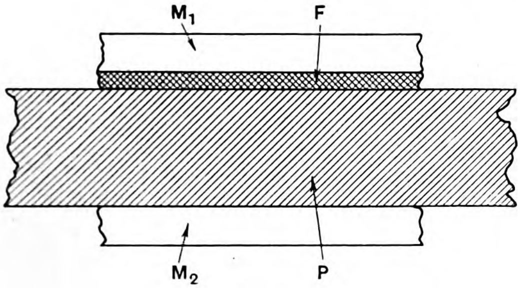


Fig. 1.

condenser is the thin chemically produced insulating film, while the electrolytic material with which the porous separator is soaked serves not only as a means of producing the insulating film but also as an electrically conducting medium to lead the current from one metal foil strip through the paper or separator to the surface of the dielectric film. This electrolytic material is thus in *series* with the dielectric film as indicated by Fig. 1. In this diagram M_1 and M_2 represent on a much enlarged scale, two metal sheets, separated by the porous separator P. On the surface of one plate M_1, the insulating film F is formed, so that this constitutes the dielectric of the condenser. The electrolyte carried by P, however, although covering a large area, and being only a thin layer, necessarily offers some resistance to the passage of current through it, so that the arrangement may be represented electrically as shown in Fig. 2, where M_1 and M_2 are the same metal plates as sketched in Fig. 1, and C represents the capacity of the insulating film F. The resistance of the electrolyte carried by P is represented by the resistance R shown in series with C in Fig. 2. The actual value of this resistance will necessarily depend upon the nature of the electrolyte used and the amount of it that is present in the interstices of the separator P (Fig. 1). In some of these condensers the value of R is apparently very small, while in others it is much larger and by no means negligible in its effect upon the condenser. The presence of the resistance in series with the true capacity portion of the condenser means that the power factor of the condenser is not good—the higher the resistance the poorer is the power factor.

The effect of such a series resistance is not only to give rise to some energy dissipation in the condenser when it is subjected to the passage of alternating currents, but it is also to lower the effective capacity of the condenser to the passage of the alternating current. The effect may be seen by reference to the diagrams in Figs. 3 and 4. In Fig. 3 the vector OI is drawn to represent the current flowing through the condenser, while the vector OC which is perpendicular to it, represents the voltage drop across the true capacity portion of the condenser. The vector OR drawn in line with the current vector OI represents the voltage drop in the equivalent series resistance of the condenser, while the vector OV which is the resultant of OC and OR, therefore represents the total terminal voltage applied to the condenser when the current OI is flowing through it. If the resistance R were not present the current through the condenser for the same applied voltage would be larger and would be represented by the vector OC' which is obtained by striking an arc with centre O through the point V, so as to intercept the prolongation of the line OC. In the case drawn in Fig. 3, it will be seen that the length OC' is very little greater than the length OC, and since these lengths are proportional to the currents which would

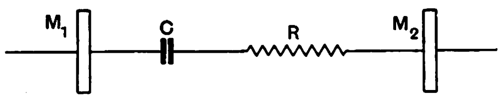


Fig. 2.

flow through the condensers under these conditions they may be taken to represent the equivalent capacities of the condenser. In Fig. 4 a similar diagram has been drawn with an arc drawn through the point C' so that the length of the vector OV is fixed and in the case drawn in this diagram the vector OR is much larger than it is in Fig. 3; or, in other words, the effective series resistance in the condenser has been assumed to be larger. The vector OV in these circumstances is therefore the resultant of the vector OR and the vector OC as before, but

B

it will be seen at once by an inspection of the diagram that the length *OC* is now very considerably less than the length *OC′*. In other words, in this case with the same voltage applied to the condenser the effective capacity of this condenser is very considerably reduced.

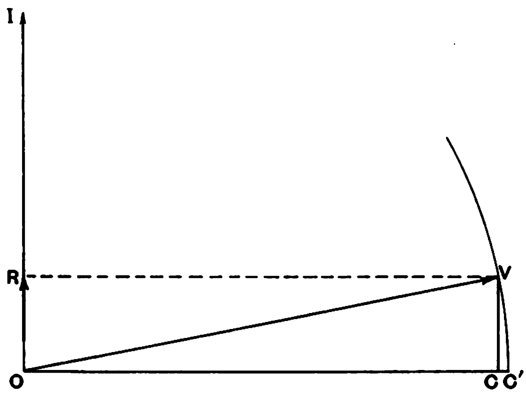


Fig. 3.

Since the voltage drop across the true capacity portion of the condenser is inversely proportional to the frequency of the current flowing through it, it will be obvious that the higher this frequency is made the more important will the series resistance effect become, or, in other words, at the higher frequencies the effect becomes more like that represented in Fig. 4 instead of like that represented in Fig. 3. The equivalent capacity of such condensers is therefore less for alternating current than it is for very low frequency or direct current.

It has already been pointed out that these dry electrolytic condensers must from their very nature possess some inherent series resistance hence their effective capacity value cannot be independent of the frequency at which they are used. Additional series resistance of not entirely inappreciable magnitude is also likely to occur in such condensers through the connections made between the terminals and the internal parts of the condensers. Such resistances should in well-designed condensers be only a small fraction of an ohm, but even such small fractions of an ohm may represent an appreciable fraction of the total impedance of the condenser. For example, a capacity of 3,000 microfarads has at a frequency of 50 cycles a reactance of only just over one ohm so that a series resistance even of a small fraction of an ohm will be quite appreciable.

Now the function of a condenser of this type is primarily to smooth out irregularities in a nominally steady direct current circuit. The effective capacity which such condensers offer to currents of the frequency of the irregularities in the direct current circuit is therefore the value which is really important in considering the action of such condensers. The voltage of direct current, as used, for example, for supplying the filaments of a valve receiver, when it is derived from a rectified alternating current source may be considered as a perfectly steady direct current voltage with a superimposed alternating ripple component. The smoothing action of the condenser is obtained from the effect of its capacity on this alternating ripple component, and the effective value of the condenser capacity at this frequency is the value which it is necessary to determine.

Measurements of the capacity of condensers of this class by direct current

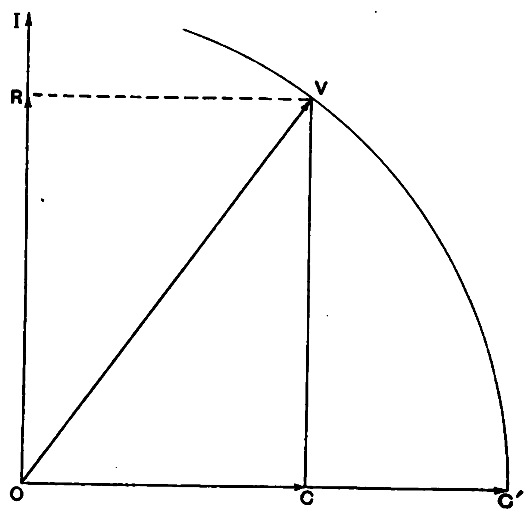


Fig. 4.

ballistic methods may therefore be of little value in determining the utility of any particular condenser when used in a filter circuit, since such measurements will usually be in error by an unknown amount. Usually the leakage resistance of condensers of this type is by no means excessively high so that

a certain proportion of the charge in the condenser will leak away between the instant of disconnecting it from the charging battery and connecting it to the discharging circuit through the ballistic galvanometer. This leakage will imply that the ballistic reading obtained is less than the true ballistic reading, so that the capacity value calculated in this way will be correspondingly reduced and may therefore approach the lower alternating capacity value of the condenser. The error due to this leakage, however, is again an unknown amount which will depend upon the particular means employed for connecting the charging and discharging circuits, and will differ from one condenser to another due to differences in their leakage resistances. Taken all round, it would seem desirable that the capacity of these condensers should be measured, if possible, under conditions which more nearly resemble the conditions under which such condensers are used. Such a method for these measurements has recently been developed in the Laboratories of the Dubilier Condenser Company and can very easily be carried out with comparatively simple apparatus. The method in question is indicated in the diagram (Fig. 5), which is a circuit diagram of the connections used for these measurements.

In this diagram P represents a potentiometer resistance of the order of 200 to 250 ohms connected across the alternating current supply circuit at 240 volts 50 cycles. Between the slider and one end of this potentiometer the primary winding of the transformer T is connected, this transformer being wound to step down the voltage from 240 to 6 volts. The secondary winding of this transformer indicated in the diagram by the heavy lines forms part of the measuring circuit which also includes the battery B, the alternating current ammeter A, the short-circuiting switch S, and the condenser to be tested C. Across the terminals of the secondary winding of the transformer T the alternating current voltmeter V is connected, this instrument being an accurately calibrated low range meter capable of giving readings to an accuracy of approximately 1/100th of a volt. The function of the battery B is to maintain a direct current voltage between the terminals of the condenser C and thus to imitate the normal working conditions under which it operates with a direct current potential between its plates. The voltage from this battery also serves " to form " and to maintain "formed" the chemical dielectric layer on the surfaces of the metal plates in the condenser. The leakage current flowing from the battery B through the condenser C usually amounts at most to 1 or 2 milliamperes and so produces a negligible error in the reading of the ammeter A. For this ammeter a Weston thermojunction ammeter or similar instrument suitable for the measurement of alternating current up to about 1.5 amperes may conveniently be used. It should be connected across a substantial short-circuiting switch S so that the meter can easily be cut out of the circuit if the current proves excessive, whether derived from the transformer T or the battery B. In carrying out a measurement of the capacity C, the

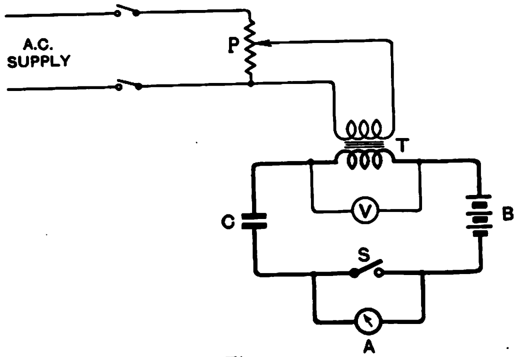


Fig. 5.

alternating current supply circuit is closed with the potentiometer P adjusted to the minimum position, and the voltage applied to the primary of the transformer T is then gradually raised while the readings of the meters V and A are observed. The potentiometer is conveniently adjusted until either the ammeter reaches a current of 1 ampere or the voltmeter reaches some definite voltage reading, such as 2 volts, whichever value is reached first. Knowing then the alternating current voltage at the terminals of the condenser and the current flowing through it the condenser capacity can be calculated from the usual formulæ, provided that the frequency of the supply is known. A correction must, however, be made before such a calculation can be carried out, since

there will be a definite but small voltage drop in the battery B, in the resistance of the ammeter A, and in the connecting wires of the circuit. Since alternating current voltmeters suitable for the accurate reading of low values of the voltage of the secondary winding of the transformer T usually require an operating current which is an appreciable fraction of an ampere, such a meter cannot be connected directly across the terminals of the condenser C without giving rise to a rather considerable error and the arrangement sketched is probably the more accurate since the transformer T can easily furnish the current necessary for the operation of the voltmeter. The resistance of the circuit and the ammeter can fairly easily be obtained by direct current measurement since at low frequencies of the order of 50 cycles the alternating current resistance of the circuit will differ from the direct current value by an entirely negligible amount. Knowing then the current flowing through the circuit as obtained from the reading of an ammeter A, the voltage drop in the resistance of the circuit can easily be calculated and since the reactance of a condenser of a few thousand microfarads is at 50 cycles only of the order of an ohm, the correction for the voltage drop in the resistance of the circuit becomes quite appreciable, even although this resistance, including the ammeter, may only be a fraction of an ohm. Usually the ammeter contributes the major portion of this resistance and may be as much as 0.25 to 0.35 ohms for a meter of the range and type mentioned above. It should be borne in mind, however, that the voltage drop in this resistance and the voltage drop across the terminals of the condenser are vectorially perpendicular and must therefore be subtracted vectorially in order to arrive at a figure for the voltage drop across the terminals of the condenser from a knowledge of the reading of the applied voltage V. Such a calculation will give a figure for the voltage across the condenser terminals corresponding to the effective capacity of the condenser under these conditions of measurement. If V is the reading of the voltmeter V, and I is the current reading on the ammeter A, while R is the resistance of the circuit, it follows that

$$V^2 = R^2I^2 + I^2/\omega^2C^2$$

whence,

$$c = \frac{1}{\omega\sqrt{(V/I)^2 - R^2}} \text{ farads}$$

$$= \frac{10^6}{\omega\sqrt{(V/I)^2 - R^2}} \text{ microfarads.}$$

A check on the measured value of the resistance R can be obtained by taking readings on two condensers separately and connecting them together in parallel, then by solving the equations resulting from applications of the above formula to each set of readings a value for the total resistance R of the circuit can be calculated. This will usually be found to be very slightly in excess of the measured resistance of the ammeter A and the wires in the circuit, the difference being due to the internal resistance of the battery B.

As an example of the extent to which the effective capacities of condensers of this type measured under alternating current conditions in this way compare with the values measured by a ballistic method, the following figures measured in this way may be quoted.

Capacity by Ballistic Method.	Alternating Current Capacity.
1,500μF.	880μF.
4,400μF.	2,620μF.
4,000μF.	2,460μF.

The results expressed by the figures in this table should not be regarded as indicating the order of magnitude of the ratio of the two "capacities" which will always be obtained. As a matter of fact, the particular readings quoted represent an extreme case arising probably from a particular method of construction which led to high internal resistance and also to a not inappreciable inductance in the internal connections of the condensers. In general the ratio of the two readings will be found to be much more nearly unity, but some difference will usually be found even with the best constructed condensers. In view of the existence of such differences arising from the method of measurement, it is suggested that some such method as has herein been outlined should always be used in carrying out tests on these condensers. Only thus can their real utility as low voltage smoothing condensers be properly gauged.

Note on the Problem of Selectivity Without Reducing the Intensity of the Sidebands.

By W. B. Lewis.

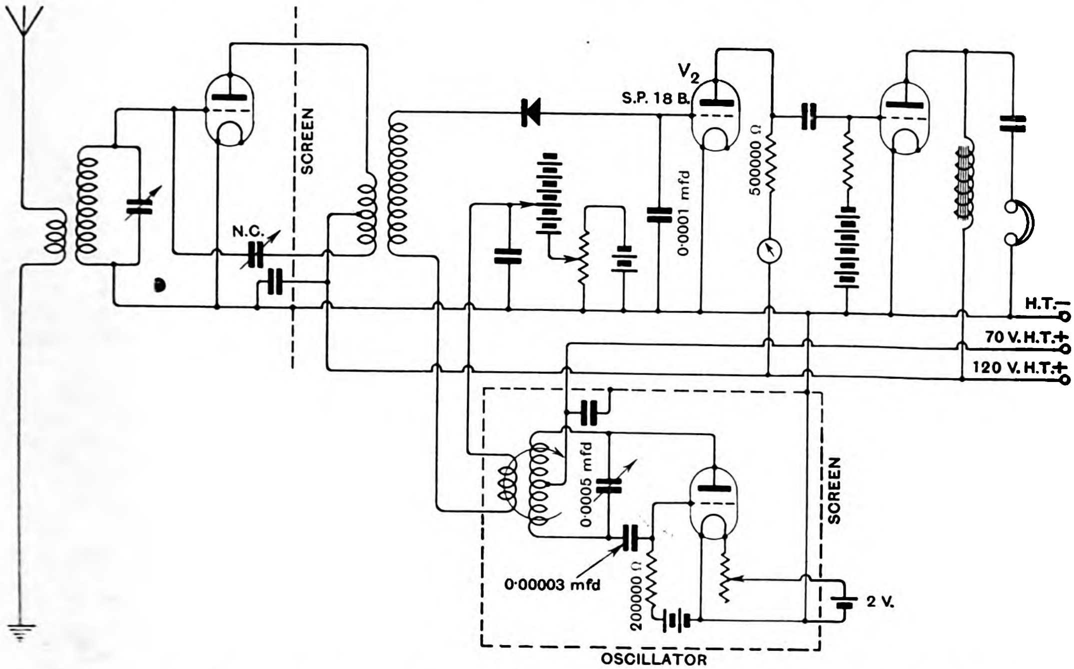
DR. BEATTY'S article in *E.W. & W.E.* for June 1928, suggests a solution of the above problem, which I have not seen mentioned. Briefly, signals are received on the Homodyne principle. The local oscillations are adjusted to be of sufficient intensity to wipe out any unwanted signals; and the H.F. amplifier is made practically aperiodic.

I may have put it too shortly to be intelligible. Suppose, for simplicity, we have an ordinary receiving set, fitted with an aperiodic H.F. amplifier, which is receiving strong but unwanted telephony (from the local station) and weak wanted telephony on a neighbouring wavelength. We couple an oscillator and tune it exactly to the carrier wavelength of the wanted station. The oscillations supplied produce a beat of infinite period with the carrier wave of the wanted station, audio frequency beats with its sidebands, and supersonic beats with the carrier and sidebands of the unwanted signal. The H.F. current supplied is made several times greater than that of the unwanted signal. After detection therefore the envelope of the H.F. current is the combination of beats mentioned above, of which only those of audio frequency will affect the ear even if others pass through the L.F. amplifier. The result is that we hear only the wanted telephony with no diminution of the higher frequencies if the amplifier is correctly designed.

The method should also be applicable to sideband telephony.

I made some experiments to test the method, and finally adopted the circuit shown in the figure.

Experiments were made on the 300-500-metre broadcast band, and the circuit was arranged so that the feed back from the oscillator to the aerial was negligible. As few alterations as were necessary were made



to the existing H.F.-Det.-L.F. set, since the experiments were only preliminary. The neutralised H.F. amplifier was left unaltered, the tuning condenser across the secondary of the H.F. transformer was removed, and the long-wave transformer (original *Wireless World* "All Wave Four" specification) plugged in. The set was made for alternative crystal or anode-bend detection. The galvanometer in the plate circuit of V_2 was used for setting the mean grid potential of V_2 to its normal value to avoid distortion. Leads were run out as shown to the oscillator, which was completely screened. The oscillation uses a 1923 D.E.R. !, + 3v. grid bias, 70v. H.T., 200,000-ohm grid leak, .00003 μF. grid-coupling condenser and .0005 μF. logarithmic tuning condenser with 4in. dial (a slow motion dial would be a great boon). The inductance is a simple solid wire, 3in. diameter, solenoid, inside which the coupling coil of about 15 turns rotates.

Anode-bend detection was abandoned as signals were not wiped out, unless the supplied oscillations overloaded the valve, even when using a P.M.4 as detector. With the crystal detector, signals were wiped out with the oscillator only very loosely coupled. Galena and zincite-tellurium seemed to answer equally well. Using a tuned H.F. transformer sufficient energy could not be supplied by the oscillator without coupling, so that the two circuits were not independent.

Results show that the principle is sound, but a rushing noise is heard in the phones which seems to originate in the crystal detector; this is not serious for loud signals. Quality is good with loud signals, but faint signals are horribly distorted; this seems partly, if not entirely, due to relative wobbling of the carrier and oscillator frequencies, As the volume is increased there seems to be a sudden transition from distortion to clarity.

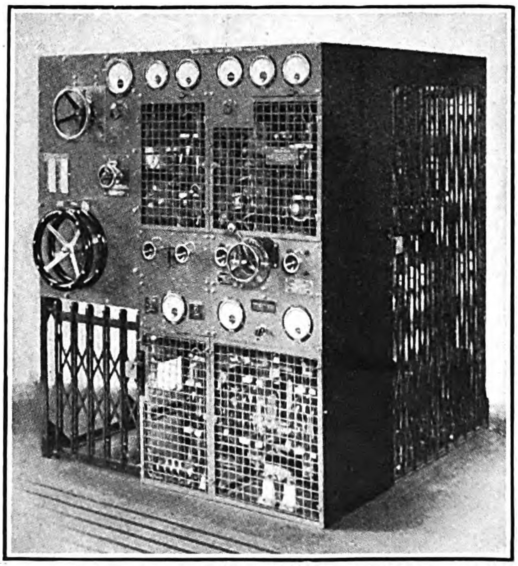
This may be serious, since 2LO at ten miles range is not completely wiped out when the aerial tuning condenser is set within three degrees of the correct setting for that station. Greater overall H.F. amplification would therefore result in an incomplete wipe out of 2LO, though avoiding distortion on a faint signal. If the local oscillations are amplified as well the rushing sound might be magnified in proportion. But no doubt improvements could be made in the linearity of the detector, the holding of the oscillator frequency, and the reduction of the rushing sound. I am writing this note at rather an early stage, as I shall be unable to continue experiments for the present.

New Commercial Apparatus.

We have received from Marconi's Wireless Telegraph Co., Ltd., description-Leaflets Nos. 1087 to 1090. These give particulars of their new types of transmitter which, although designed specially to meet naval requirements, are equally suitable for use in land stations. The accompanying illustration is of Type TN1, having a nominal input of 5 kW. and an aerial rating of 2 kW. Type TN2 has an aerial rating of 1 kW.; TN4, TN5 and TN5*a* are smaller sets ranging from 350 watts to 75 watts respectively in the aerial circuit when used on I.C.W. telegraphy.

In the TN1 and TN2 transmitters I.C.W. signalling can be effected on any one of three selected note frequencies, thus allowing distinction notes to be used by different ships working on the same wavelength, and telephony transmission can be provided if required. The wave-range is from 400 to 3,000 metres.

Type TN4 is designed for fire control on destroyers, cruisers and battleships, and has a wave-range of 80 to 180 metres. Type TN5 has an effective range of about 50 nautical miles on wavelengths between 100 and 150 metres, and Type TN5*a*, intended for small craft, has a working range of about 10 nautical miles on wavelengths of 40 to 1,200 metres.



Marconi Type TN1 transmitter.

Effect of Anode-Grid Capacity in Anode-Bend Rectifiers.

By E. A. Biedermann, B.Sc., A.M.I.E.E.

(Concluded from page 76 of February issue.)

Effect of Anode-grid Capacity on Wave-form of Rectified Audio-frequency Current.

We have so far considered only the extent to which the feed-back affects the magnitude and phase shift of the individual side-bands of the grid-filament potential difference. The true criterion of the effect of the feed-back is, however, the extent of its effect on the wave-form of the rectified audio-frequency current in the anode circuit. A certain amount of distortion of the wave-form of this current is in any case produced, as is well known, by the imperfect functioning of the valve as a detector.

In the first place, a parasitic component of double the modulation frequency of the input potential difference is produced, and if the ratio of the external anode circuit impedance to the total impedance of the anode circuit, including the valve resistance, is not practically independent of the audio-frequency, a certain amount of distortion is inevitably introduced. These are inherent imperfections of a detector valve, and are in no way due to the anode-grid capacity of the valve. We are now concerned only to find to what extent, if any, additional distortion of the audio-frequency wave-form is caused by this capacity.

In order to determine this it is necessary to consider briefly the theory of the action of a valve as an anode-bend detector.

This subject has been dealt with in considerable detail in this journal by F. M. Colebrook,* but he discussed only the case of a modulated input potential difference of the form

$$\begin{aligned} e &= (E_0 + E_1 \sin mt) \sin \omega t \\ &= \{E_0 \sin \omega t - \tfrac{1}{2}E_1 \cos (\omega + m)t \\ &\qquad + \tfrac{1}{2}E_1 \cos (\omega - m)t\} \end{aligned}$$

that is, the magnitudes of the positive and negative side-bands were equal and there was no phase shift relatively to the carrier-wave component. Actually, as we have seen, the positive and negative side-band components will not be quite equal, and are always out of phase with the carrier-wave component, and this to a slightly unequal extent. This is so even in the case of a valve having no appreciable anode-grid capacity.

If we take both these factors into account, we have an input potential difference of the form

$$\begin{aligned} e = \{E_0 \sin \omega t - \tfrac{1}{2}\lambda_1 E_1 \cos \\ ((\omega + m)t + \phi_1) + \tfrac{1}{2}\lambda_2 E_1 \cos \\ ((\omega - m)t + \phi_2)\} \quad .. \quad (28) \end{aligned}$$

We have seen that the anode-grid capacity affects the magnitude of the carrier-wave component but produces no phase shift of it. E_0 is supposed to represent the actual magnitude of the carrier-wave component as modified by the increased resistance of the input circuit caused by the feed-back. Similarly E_1 denotes the actual magnitude which the modulation component would have at a very small audio-frequency. With this understanding, reference to (26) and (27) shows that the values of $\lambda_1, \lambda_2, \phi_1, \phi_2$ in the above expression are given by

$$\left.\begin{aligned} \lambda_1 &= \frac{\left(1 + B\frac{m}{\omega_c}\right)}{\sqrt{1 + \frac{4m^2L^2}{r_0^2}}}, \\ \lambda_2 &= \frac{\left(1 - B\frac{m}{\omega_c}\right)}{\sqrt{1 + \frac{4m^2L^2}{r_0^2}}} \\ \tan \phi_1 &= -\left(1 + \beta\frac{m}{\omega_c} + \gamma\frac{m^2}{\omega_c^2}\right)\frac{2mL}{r_0} \\ \tan \phi_2 &= \left(1 - \beta\frac{m}{\omega_c} + \gamma\frac{m^2}{\omega_c^2}\right)\frac{2mL}{r_0} \end{aligned}\right\} \quad ..(29)$$

* "The Rectification of Small Radio-Frequency Potential Differences by Means of Triode Valves," by F. M. Colebrook (*E.W. & W.E.*, Jan., 1926).

where m is now to be regarded as a positive quantity, so that $-m$ has been substituted for m in deriving the formulæ for λ_2 and $\tan\phi_2$, which have reference to the negative side-band.

Now if we examine, in the article referred to above, the analysis by which the value of the rectified current is derived, we find that it is determined by the equation

$$i + \frac{v}{r_a} = k\frac{1}{T}\int_0^T e^2 dt$$

where i denotes the total increase of anode circuit current due to the applied potential difference e, v the voltage drop in the anode circuit produced by this increment of current, T is the radio-frequency period, and k a constant depending only on the valve characteristics.

Evaluating the integral for a potential difference of the form (28), we obtain

$$\begin{aligned} i + \frac{v}{r_a} = k\Big\{ &\tfrac{1}{2}\{E_0^2 + \tfrac{1}{4}(\lambda_1^2 + \lambda_2^2)E_1^2\} \\ &+ \tfrac{1}{2}\sqrt{\lambda_1^2 + \lambda_2^2 + 2\lambda_1\lambda_2\cos(\phi_1+\phi_2)}\,\sin(mt+\phi_0)E_0E_1 \\ &- \tfrac{1}{4}\lambda_1\lambda_2\cos(2mt+\phi_1-\phi_2)E_1^2\Big\} \end{aligned}$$

where $\tan\phi_0 = \dfrac{(\lambda_1\sin\phi_1 - \lambda_2\sin\phi_2)}{(\lambda_1\cos\phi_1 + \lambda_2\cos\phi_2)}$

Hence, denoting by i_m, i_{2m}, v_m, v_{2m} the components of rectified current and voltage drop of frequencies $\frac{m}{2\pi}$ and $\frac{m}{\pi}$ respectively, we obtain

$$i_m + \frac{v_m}{r_a} = \tfrac{1}{2}k\sqrt{\lambda_1^2 + \lambda_2^2 + 2\lambda_1\lambda_2\cos(\phi_1+\phi_2)}\,\sin(mt+\phi_0)E_0E_1$$

$$i_{2m} + \frac{v_{2m}}{r_a} = -\tfrac{1}{4}k\lambda_1\lambda_2\cos(2mt+\phi_1-\phi_2)E_1^2$$

These expressions give the instantaneous values of current and voltage drop with reference to variations of audio-frequency. The corresponding maximum values of the current components are, therefore,

$$\left.\begin{aligned} I_m &= \frac{\tfrac{1}{2}kr_a}{\sqrt{(r_a+R_a)^2 + X_m^2}} \times \sqrt{\lambda_1^2 + \lambda_2^2 + 2\lambda_1\lambda_2\cos(\phi_1+\phi_2)}\,E_0E_1 \\ I_{2m} &= \frac{\tfrac{1}{4}kr_a}{\sqrt{(r_a+R_a)^2 + X_{2m}^2}}\lambda_1\lambda_2E_1^2 \end{aligned}\right\} \quad (30)$$

where X_m, X_{2m} denote the reactances of the external anode circuit for the frequencies $\frac{m}{2\pi}$, $\frac{m}{\pi}$, while the phase shift of the $\frac{m}{2\pi}$ frequency component is given by

$$\tan\phi_0 = \frac{(\lambda_1\sin\phi_1 - \lambda_2\sin\phi_2)}{(\lambda_1\cos\phi_1 + \lambda_2\cos\phi_2)} \quad \ldots (31)$$

From (29) we have

$$\tan(\phi_1+\phi_2) = \frac{-4\beta\dfrac{m^2L}{\omega_c r_0}}{\left\{1 + \left(1 + (2\gamma-\beta^2)\dfrac{m^2}{\omega_c^2}\right)\dfrac{4m^2L^2}{r_0^2}\right\}}$$

Neglecting for the moment the effect of the small term $(2\gamma-\beta^2)\frac{m^2}{\omega_c^2}$, the maximum possible value of this expression with reference to $\frac{mL}{r_0}$ is $\beta\frac{m}{\omega_c}$. Since

$$\cos(\phi_1+\phi_2) = \{1 + \tan^2(\phi_1+\phi_2)\}^{-\frac{1}{2}},$$

we can therefore put

$$\cos(\phi_1+\phi_2) = \{1 - \tfrac{1}{2}\tan^2(\phi_1+\phi_2)\}$$

neglecting only quantities of the order $\beta^4\frac{m^4}{\omega_c^4}$, so that

$$\begin{aligned} \cos(\phi_1+\phi_2) &= 1 - \frac{8\beta^2\left(\dfrac{mL}{r_0}\right)^2\dfrac{m^2}{\omega_c^2}}{\left\{1+\left(1+(2\gamma-\beta^2)\dfrac{m^2}{\omega_c^2}\right)\dfrac{4m^2L^2}{r_0^2}\right\}^2} \\ &= 1 - \frac{8\beta^2\left(\dfrac{mL}{r_0}\right)^2\dfrac{m^2}{\omega_c^2}}{\left(1+\dfrac{4m^2L^2}{r_0^2}\right)^2} \end{aligned}$$

neglecting only quantities of the order $\beta^2(2\gamma-\beta^2)\frac{m^4}{\omega_c^4}$.

Hence, we have

$$\left.\begin{aligned} \cos(\phi_1+\phi_2) &= \left(1 - 2C\frac{m^2}{\omega_c^2}\right) \\ \text{where}\quad C &= \frac{\beta^2\left(\dfrac{2mL}{r_0}\right)^2}{\left(1+\dfrac{4m^2L^2}{r_0^2}\right)^2} \end{aligned}\right\} \quad \ldots (32)$$

which is essentially less than $\frac{1}{4}\beta^2$.

From (29) we therefore find

$$\sqrt{\lambda_1^2 + \lambda_2^2 + 2\lambda_1\lambda_2 \cos(\phi_1 + \phi_2)}$$

$$= \frac{\sqrt{2+2B^2\frac{m^2}{\omega_c^2}+2\left(1-B^2\frac{m^2}{\omega_c^2}\right)\left(1-2C\frac{m^2}{\omega_c^2}\right)}}{\sqrt{1+\frac{4m^2L^2}{r_0^2}}}$$

$$= \frac{2}{\sqrt{1+\frac{4m^2L^2}{r_0^2}}}\left(1-\tfrac{1}{2}C\frac{m^2}{\omega_c^2}\right)$$

while

$$\lambda_1\lambda_2 = \frac{\left(1 - B^2\frac{m^2}{\omega_c^2}\right)}{\left(1+\frac{4m^2L^2}{r_0^2}\right)}.$$

Substituting these values in (30) we obtain

$$\left.\begin{aligned} I_m &= \frac{kr_a}{\sqrt{(r_a+R_a)^2+X_m^2}}\,\frac{\left(1-\frac{1}{2}C\frac{m^2}{\omega_c^2}\right)}{\sqrt{1+\frac{4m^2L^2}{r_0^2}}}E_0E_1 \\ I_{2m} &= \frac{\frac{1}{4}kr_a}{\sqrt{(r_a+R_a)^2+X_{2m}^2}}\,\frac{\left(1-B^2\frac{m^2}{\omega_c^2}\right)}{\left(1+\frac{4m^2L^2}{r_0^2}\right)}E_1^2 \end{aligned}\right\} \quad \ldots \quad (33).$$

Thus the small term involving the first power of $\frac{m}{\omega_c}$ which was present in the expression for the potential difference does not appear at all in the expressions for the rectified current components, and there remain only terms of the order $\frac{m^2}{\omega_c^2}$, which are negligibly small since the coefficients B and C will never much exceed unity.

Thus, so far as the magnitudes of these two current components are concerned, the effect of the anode-grid capacity of the valve is for all practical purposes solely that arising from the increase of the input circuit resistance which it causes.

The effect of this is clearly to cause a smaller variation in the values of I_m, I_{2m} with frequency than would occur if the valve had no appreciable anode-grid capacity.

The ratio of the parasitic current component I_{2m} to the modulation frequency component I_m is

$$\frac{I_{2m}}{I_m} = \frac{\sqrt{(r_a+R_a)^2+X_m^2}}{\sqrt{(r_a+R_a)^2+X_{2m}^2}}\;\frac{1}{4\sqrt{1+\frac{4m^2L^2}{r_0^2}}}\;\frac{E_1}{E_0} \quad \ldots \quad (34)$$

neglecting the small terms $B^2\frac{m^2}{\omega_c^2}$ and $\frac{1}{2}C\frac{m^2}{\omega_c^2}$.

Thus this ratio is greater than it would be in the case of a valve with negligible anode-grid capacity only to the extent that it is increased by the increase of resistance of the input circuit from r to r_0.

Lastly, to determine the extent of the phase shift of I_m, we have from (29) and (31)

$$\tan\phi_0 = -\frac{\left\{\lambda_1\left(1+\beta\frac{m}{\omega_c}+\gamma\frac{m^2}{\omega_c^2}\right)\cos\phi_1 + \lambda_2\left(1-\beta\frac{m}{\omega_c}+\gamma\frac{m^2}{\omega_c^2}\right)\cos\phi_2\right\}\frac{2mL}{r_0}}{(\lambda_1\cos\phi_1+\lambda_2\cos\phi_2)}$$

$$= -\left\{\left(1+\gamma\frac{m^2}{\omega_c^2}\right) + \frac{(\lambda_1\cos\phi_1-\lambda_2\cos\phi_2)\,\beta\frac{m}{\omega_c}}{(\lambda_1\cos\phi_1+\lambda_2\cos\phi_2)}\right\}\frac{2mL}{r_0}$$

In evaluating the coefficient of $\frac{m}{\omega_c}$ we need only retain the first power of $\frac{m}{\omega_c}$. Therefore

$$\cos\phi_1 = (1+\tan^2\phi_1)^{-\frac{1}{2}}$$

$$= \left\{1+\left(1+\beta\frac{m}{\omega_c}+\gamma\frac{m^2}{\omega_c^2}\right)^2\frac{4m^2L^2}{r_0^2}\right\}^{-\frac{1}{2}}$$

$$= \left\{\left(1+\frac{4m^2L^2}{r_0^2}\right)+\frac{4m^2L^2}{r_0^2}2\beta\frac{m}{\omega_c}\right\}^{-\frac{1}{2}}$$

$$= \left(1+\frac{4m^2L^2}{r_0^2}\right)^{-\frac{1}{2}}\left(1-b\beta\frac{m}{\omega_c}\right)$$

where

$$b = \frac{\frac{4m^2L^2}{r_0^2}}{\left(1+\frac{4m^2L^2}{r_0^2}\right)}.$$

Similarly

$$\cos\phi_2 = \left(1+\frac{4m^2L^2}{r_0^2}\right)^{-\frac{1}{2}}\left(1+b\beta\frac{m}{\omega_c}\right)$$

Hence

$$\frac{(\lambda_1 \cos \phi_1 - \lambda_2 \cos \phi_2)}{(\lambda_1 \cos \phi_1 + \lambda_2 \cos \phi_2)} =$$

$$\frac{\left\{\left(1+B\frac{m}{\omega_c}\right)\left(1-b\beta\frac{m}{\omega_c}\right)-\left(1-B\frac{m}{\omega_c}\right)\left(1+b\beta\frac{m}{\omega_c}\right)\right\}}{\left\{\left(1+B\frac{m}{\omega_c}\right)\left(1-b\beta\frac{m}{\omega_c}\right)+\left(1-B\frac{m}{\omega_c}\right)\left(1+b\beta\frac{m}{\omega_c}\right)\right\}}$$

$$= (B - b\beta)\frac{m}{\omega_c},$$

so that

$$\tan \phi_0 = -\left\{1 + \left((B - b\beta)\,\beta + \gamma\right)\frac{m^2}{\omega_c^2}\right\}\frac{2mL}{r_0}$$

Since B, b, β and γ are all comparable with unity, $\tan \phi_0$ only differs by a negligible amount from

$$\tan \phi_0 = -\frac{2mL}{r_0} \quad \cdots \quad \cdots \quad (35)$$

Thus as regards the phase shift of the modulation frequency component of the rectified current, also, the effect of the anode-grid capacity of the valve is solely that arising from the increase of the input circuit resistance which it causes, and this increase causes a decrease of phase shift.

In the whole of the above analysis we have neglected, compared with unity, only terms of the order $\frac{r_0^2}{\omega_c^2 L^2}$, $\left(\frac{r_0}{\omega_c L}\right)\frac{m^2}{\omega_c^2}$ and $\frac{m^3}{\omega_c^3}$, and the final conclusion we reach is that, except for a negligibly small effect of the order $\frac{m^2}{\omega_c^2}$ compared with unity, the sole effect of the anode-grid capacity is to increase the effective resistance of the input circuit, which results, not in an increase of distortion, but in all respects in a reduction of distortion, though possibly to a very slight extent. On the other hand, any such increase of resistance means reduced sensitivity and selectivity, and before concluding it will be of interest to find what degree of increase in the effective resistance is to be expected.

The Increase of Input Circuit Resistance due to Anode-grid Capacity.

The effective resistance r_0 of the input circuit as increased by the feed-back is given by

$$r_0 = (r + \phi(\omega_c)\omega_c^4 L^2 C_{ga})$$

$$= \left[r + \frac{r_a\left\{\mu C_a + \left(\mu + 1 + \frac{r_a}{R_a}\right)C_{ga}\right\}\omega_c^4 L^2 C_{ga}}{\left\{\left(1+\frac{r_a}{R_a}\right)^2 + r_a^2\omega_c^2(C_a + C_{ga})^2\right\}}\right] \quad \cdots \quad \cdots \quad (36)$$

where r is the inherent resistance of the input circuit. In general, $r_a^2\omega_c^2(C_a + C_{ga})^2$ will be much greater than $\left(1 + \frac{r_a}{R_a}\right)^2$. Since, also, C_{ga} will usually be small compared with C_a, we have—at least as a rough approximation—

$$r_0 = \left\{r + \mu\frac{\omega_c^2 L^2}{r_a}\left(\frac{C_{ga}}{C_a + C_{ga}}\right)\right\}$$

Thus the increase of resistance is independent of the inherent resistance of the circuit, and will be greater the greater the reactance $\omega_c L$ of the circuit. It will therefore be greater for circuits intended for long-wave reception than for those for short waves. Further, since $\frac{\omega_c L}{r}$ will be about the same in both cases, the percentage increase will also be greater in the case of the long-wave circuit, since

$$\frac{r_0}{r} = \left\{1 + \mu\left(\frac{\omega_c L}{r}\right)\left(\frac{\omega_c L}{r_a}\right)\left(\frac{C_{ga}}{C_a + C_{ga}}\right)\right\}$$

The increase of resistance is also roughly proportional to the amplification factor, and is inversely proportional to the A.C. anode resistance of the valve. While the former is relatively small, and the latter relatively large in the case of an anode-bend detector, the ratio $\frac{\mu}{r_a}$ will be much greater in the case of a grid-leak detector, so that in the latter case a very considerable resistance load may be imposed on the input circuit, in addition to that due to the grid current.

In the case of an anode-bend detector, however, the increase of resistance is not nearly as large as is deduced in Mr. Medlam's article. For a particular case where $C_{ga} = 5\mu\mu$F., $C_a = 50\mu\mu$F., $r_a = 10^5$, $\omega_c L = 1{,}500$ and frequency 800 kilocycles, he finds an increase of resistance of 100 per cent. for the very low value of $\mu = 0.15$. His formula does not involve the initial resistance of the input circuit, but if we take $r = 15$ ohms, which is quite a reasonable

figure for a reactance of 1,500 ohms, we find from the accurate formula (36) (with $\frac{r_a}{R_a} = 0$), $\frac{r_0}{r} = 1.033$, *i.e.*, an increase of only some 3 per cent.

For a long-wave coil with $\omega_c L$, say, equal to 6,000 ohms and a proportionate increase of resistance, we should have $\frac{r_0}{r} = 1.132$, an increase of still only 13 per cent.

On the other hand, with a valve working as a grid-leak detector with an amplification factor of 10 and impedance of 20,000 ohms, and allowing for an initial increase of the resistance by 100 per cent. due to grid current, the resistance would be further increased four and a half times by the feed-back in the case of the short-wave circuit and about sixteen times in the case of the long-wave circuit.

The only means by which this increase of resistance can be reduced is to reduce the ratio $\left(\frac{C_{ga}}{C_a + C_{ga}}\right)$, *i.e.*, increase the ratio $\frac{C_a}{C_{ga}}$ as far as is compatible with other considerations. Thus, if we make $C_a = 300\mu\mu$F. instead of $50\mu\mu$F., the resistance would only be increased by about 60 per cent. in the one case and by 260 per cent. in the other.

In the case of the anode-bend detector, however, we can safely conclude that only a comparatively small percentage increase of resistance will be caused by the feed-back through the anode-grid capacity of the valve.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Transmitting Station actually sends out Waves of one Definite Frequency, but of Varying Amplitude.

To the Editor, E.W. & W.E.

SIR,—With reference to Mr. Aughtie's letter on the above subject in your December issue, the following may perhaps help to explain the "apparent fallacy" which he expounds. His argument is as follows: If a carrier wave of frequency, say, 1,000 kc., modulated with a 1 kc. note, is regarded as consisting of a combination of frequencies 999, 1,000 and 1,001, then when amplified by a non-linear amplifier, frequencies 1,998, 2,000, and 2,002 will, among others, be introduced, and consequently when a receiver is tuned to 2,000 kc., there should be heard a note of 2 kc., and, in general, all notes should be raised an octave, whereas experiment shows that a 1 kc. note is heard on all harmonics of the carrier-wave.

His conclusion is that when dealing with a valve it is not legitimate to regard a complex waveform as a sum of pure harmonics of constant amplitude. Thus if the complex waveform is represented by

$$e = E_0 \sin \omega t + E_1 \sin mt \sin \omega t$$

we must not express this in the equivalent form

$$e = E_0 \sin \omega t + \tfrac{1}{2}E_1 \cos (\omega - m)t - \tfrac{1}{2}E_1 \cos (\omega + m)t$$

when we wish to examine the effect of applying such a voltage to a valve.

In other words, the properties of a wireless valve are so peculiar as to render invalid an elementary trigonometrical transformation! The mere statement of Mr. Aughtie's conclusion in this form is sufficient, I think, to show that there certainly *is* a fallacy in his argument. It arises from the fact that he concentrates on consideration of certain frequencies which are produced under the assumed conditions to the entire exclusion of certain other frequencies which are also produced, and produced, moreover, with a much greater amplitude than the particular ones he considers.

The second harmonic of the carrier frequency produced by the assumed non-linear amplifier arises primarily from the introduction of a voltage component proportional to the square of the impressed voltage—*i.e.*, proportional to

$$\{E_0 \sin \omega t + \tfrac{1}{2}E_1 \cos (\omega - m)t - \tfrac{1}{2}E_1 \cos (\omega + m)t\}^2$$

$$\begin{aligned} = \{&E_0^2 \sin^2 \omega t + \tfrac{1}{4}E_1^2 \cos^2 (\omega - m)t \\ &+ \tfrac{1}{4}E_1^2 \cos^2 (\omega + m)t \\ &- \tfrac{1}{2}E_1^2 \cos (\omega - m)t \cos (\omega + m)t \\ &+ E_0 E_1 \sin \omega t (\cos (\omega - m)t - \cos (\omega + m)t)\} \end{aligned}$$

$$\begin{aligned} = \{&\tfrac{1}{2}E_0^2(1 - \cos 2\omega t) + \tfrac{1}{8}E_1^2 (1 + \cos 2(\omega - m)t) \\ &+ \tfrac{1}{8}E_1^2 (1 + \cos 2(\omega + m)t) - \tfrac{1}{4}E_1^2 (\cos 2\omega t \\ &+ \cos 2mt) + E_0E_1 \sin mt (1 - \cos 2\omega t)\} \end{aligned}$$

The terms involving the second harmonic of the carrier frequency are

$$\begin{aligned} -\{&\tfrac{1}{2}E_0^2 \cos 2\omega t - \tfrac{1}{8}E_1^2 \cos 2(\omega - m)t \\ &- \tfrac{1}{8}E_1^2 \cos 2(\omega + m)t + \tfrac{1}{4}E_1^2 \cos 2\omega t \\ &+ E_0E_1 \sin mt \cos 2\omega t\} \end{aligned}$$

In effect, what Mr. Aughtie has done in his argument is to take account of the components represented by the first four terms, but has entirely neglected the component represented by the term $E_0E_1 \sin mt \cos 2\omega t$, which is the second harmonic of the carrier wave *modulated with the original note frequency* $\frac{m}{2\pi}$.

A valve detector rectifies primarily in virtue of the fact that it produces a current or voltage proportional to the *square* of the impressed voltage.

Writing the above expression in the form

$$-\{\tfrac{1}{2}(E_0^2 + \tfrac{1}{2}E_1^2) - \tfrac{1}{4}E_1^2 \cos 2mt + E_0E_1 \sin mt\}\cos 2\omega t$$

the rectified current or voltage will therefore be proportional to

$$\{\tfrac{1}{2}(E_0^2 + \tfrac{1}{2}E_1^2) - \tfrac{1}{4}E_1^2 \cos 2mt + E_0E_1 \sin mt\}^2$$
$$= \{\tfrac{1}{4}(E_0^2 + \tfrac{1}{2}E_1^2)^2 + \tfrac{1}{16}E_1^4 \cos^2 2mt + E_0^2E_1^2 \sin^2 mt - \tfrac{1}{4}(E_0^2 + \tfrac{1}{2}E_1^2) E_1^2 \cos 2mt + (E_0^2 + \tfrac{1}{2}E_1^2) E_0E_1 \sin mt - \tfrac{1}{2}E_0E_1^3 \sin mt \cos 2mt\}$$

On reducing this to a sum of harmonic frequencies, we find for the first and second harmonics

$$(E_0^2 + \tfrac{3}{4}E_1^2) E_0E_1 \sin mt$$

and

$$-(\tfrac{3}{4}E_0^2 + \tfrac{1}{8}E_1^2)E_1^2 \cos 2mt$$

This not only is the fundamental note frequency reproduced, as well as the second and higher harmonics, when receiving the second harmonic of the carrier wave, but the amplitude of the second harmonic of the note frequency is less than $\frac{3}{4}\frac{E_1}{E_0}$ of the amplitude of the fundamental note frequency.

The above analysis is, of course, only approximate, since we have taken account only of the terms depending on the square of the voltage impressed on the assumed non-linear amplifier, and only of that part of the rectified current or voltage depending on the square of the voltage (of double the carrier wave frequency) impressed on the detector valve. It is quite sufficient, however, to show that the main effect to be expected when listening to the second harmonic of the carrier wave frequency is a reproduction of the original note frequencies.

The analysis could have been considerably simplified by dealing with the voltage in the form

$$e = E_0 \sin \omega t + E_1 \sin mt \sin \omega t$$

with, of course, exactly the same result, but Mr. Aughtie would no doubt then have claimed that I was really only supporting his own conclusion.

E. A. BIEDERMANN.

Brighton.
January 1st, 1929.

Alignment Valve Characteristics.

To the Editor, E.W. & W.E.

SIR,—Referring to Mr. W. A. Barclay's letter in your February issue, I agree that the alignment chart in question could have been constructed more accurately from a knowledge of the observed data. The object of the above article, however, was to show how the valve characteristics could be obtained fairly approximately and easily, before the manufacture of the valve. The method employed makes use of the valve design data only, and enables the characteristics to be obtained without having to make tedious calculations consisting of repeated substitutions in a formula. In these circumstances, since the approximate shape of the characteristics is sufficient it was assumed that the Van de Bijl formula would give the necessary accuracy. The method of obtaining the constants for this formula were not given as it was thought that this part of the subject had been treated quite fully by other writers.

M. REED.

"The Allocation of Wavelengths to European Broadcasting Stations."

Mr. Siffer Lemoine has asked us to point out that in connection with his article on "The Allocation of Wavelengths to European Broadcasting Stations," published in our issue of July, 1928, the reference made in our editorial in our issue of January, 1929, is misleading, and is due to a mistranslation of his original text.

The translation of the sentence in question should have read :—

"The scheme worked out at Geneva by L'Union Internationale de Radiophonie, which came into operation in November, 1926, and to which most of the broadcasting organisations in Europe have given their adherence, has undoubtedly meant an important step forward, in spite of the deficiencies that mar it, and although the plan in question cannot be regarded as representing a definite solution."

Book Review.

DONNÉES NUMÉRIQUES DE RADIOÉLECTRICITÉ (T.S.F.). By R. Mesny. Extrait du Vol. VI des Tables Annuelles de Constantes (1923–1924) —1 Vol. in 4° de 26 pp. Price, 15 Fr.; bound 30 Fr. Gauthier-Villars et Cie, 55, Quai des Grand-Augustins, Paris (vi°).

The international committee which controls the Tables Annuelles de Constantes has decided to publish in separate parts a certain number of the chapters contained in Vol. VI, and the section under review contains the constants and data dealing with radio telegraphy and telephony. It would have been a great convenience to have had this data in such a convenient form and at such a reasonable price, but it must be pointed out that the data is limited to that published during the two years 1923–1924, and is therefore not only very limited in its scope but in a subject developing so rapidly, it is now necessarily out of date. The material is divided into eight sections. The first entitled thermionic tubes gives characteristic curves of a number of valves, now five years old. The second section deals with the valve as a detector and the influence of alkali vapour on the characteristic; then follows tables of permeability of iron and nickel at high frequencies. The fourth and fifth sections give the results of many measurements made on wave attenuation mainly with long waves five or six years ago. A section follows on direction finding and then a miscellaneous collection of data on various subjects which could not be classified. The final section contains tables for the calculation of inductance of coils of various shapes.

A set of volumes like this covering the last twenty years and brought right up to date would be very useful, but this one isolated volume only serves to remind us how far we have travelled since 1924.

The Development of the Oxide-coated Filament.

(Paper by Dr. B. Hodgson, O.B.E., and Messrs. L. S. Hartley, B.Sc., A.M.I.E.E., and O. S. Pratt, B.A., read before the Wireless Section, I.E.E., on 6th February, 1929.)

ABSTRACT.

In the introductory portion, the paper traces the origin of the coated filament from the first lime-coated cathode of Wehnelt in 1904. Physical study led to the assumption that there were free electrons in a metallic conductor in a state of violent motion, like the molecules of a gas or liquid. This increases with temperature until the energy of these motions attains a value large enough to carry some of the electrons through the surface of the hot body. The electrons have to overcome forces acting at the boundary, as do the molecules of a vaporising solid or liquid.

Richardson gave his equation for emission in the well-known form

$$I = AT^2e^{-b/T}$$

where A is a constant, and $b = \phi e/k$, k being Boltzmann's constant, and ϕ the voltage level the energy of the electron must attain to break through the forces resisting its escape from the emitting surface.

The emission constants of the oxide-coated filament are then discussed, micropyrometric measurements showing an emissive improvement of a hundredfold or more by formation of the oxide coating.

TABLE II.

Material.	A	b	ϕ
	amps./cm²/deg. C.	deg. C.	volts.
Tungsten ..	60.12	52 560	4.53
	—	56 000	4.46
	100	53 100	4.57
Thorium ..	70	39 400	3.27
		34 100	2.94
Calcium oxide ..	—	21 400	1.77
		—	2.24
		—	2.4–2.5
Strontium oxide	—	15 300	1.27
		—	1.79
		—	2.15
Barium oxide ..	—	12 000	0.99
		—	1.59
		—	1.85
Mixture of barium and strontium oxides ..	0.001	12 100	1.04

Table II gives some values for different materials, showing the variation of A, b and ϕ, it being noted that A varies with the material, and does not keep the constant value (viz., of about 60) indicated by theory.

The Mechanism of Emission.

After discussing early theories of emission from the oxide-coated filament, the authors give the present theory. According to this, the barium oxide is decomposed electrolytically and oxygen is diffused into the vacuous space, while the alkaline earth metal remains at first where it was liberated, but subsequently diffuses to the surface where it forms small islands which are emission centres in the sense of Richardson's law (*i.e.*, thermionically). Everything that helps the building of these islands increases the emissivity of the filament. The emission thus becomes constant when equilibrium is reached between the evaporation of the metal and the building of new metal islands under the electrolysis set up by the emission current.

Various experiments and facts in support of this theory are mentioned. One (by Koller) was to take a filament with the maximum number of metallic islands and giving a work function of 1.04 volts. After glowing the filament at a high temperature and boiling off the barium (leaving a barium oxide filament), the work function had increased to 3.1 v., showing that the emission was due to metallic particles produced by electrolysis by the anode current.

Another is the known fact that a filament is partially de-activated if run for considerable periods without emission current, the supply of metallic particles due to electrolysis not being maintained. It can be re-activated by running with high anode voltage and large emission current, due to the re-electrolysis of the oxide and the re-formation of the metal.

One difficulty of the theory is why a volatile metal like barium remains on the surface after formation. (Barium melts at about 1120 deg. K., and vaporises at 1220 deg. K.). It is suggested that it may not be in the form of drops or separate particles, but perhaps in some adsorbed atomic condition which holds it fast to the surface. It is known that, with a tungsten filament in vapours of cæsium, rubidium and potassium, these metals adhere to the tungsten at temperatures higher than would be expected from the known vapour pressures of the metals. Experiments by the authors showed that valves with barium filaments lost their emission very quickly, while those with barium oxide filaments showed little change in thousands of hours. It thus appears that the oxide si essential as a support or carrier for the barium which would otherwise vaporise.

The Manufacture of the Barium Oxide Filament.

These filaments can be made in one of four ways :

(1) Melting or fusing of a barium compound to the core wire.

(2) Application to the wire of a resinous or paraffin paste containing a barium compound.

(3) Evaporation of a solution of a barium salt which is painted on the wire.

(4) Deposition on the filament of barium from vapour.

In the first method, the core wire of platinum or nickel is drawn through the fused salt bath. This gives a rough filament and a loosely adhering coating and is not now in much use.

In the second method, the prepared paste is applied to the heated filament, so that a portion of it adheres. The wire is then heated more strongly

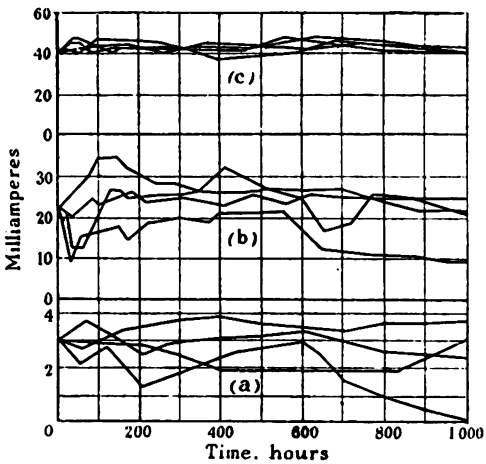


Fig. 2.—*Variation of saturation current from various oxide-coated cathodes with life.*

to evaporate the paraffin or resinous carrier. Finally, the core is heated to about 1,000 deg. C. to sinter the substance to the wire and convert the carbonate of the paste to oxide, this being repeated several times. A process of this nature is used by Standard Telephones and Cables. The resulting filaments are greyish and slightly rough in texture, but can be made regular along the length of the filament. The core metal is usually platinum or nickel. If too thick, the layer tends to crack. The filament must be protected, before pumping, from the action of carbon dioxide and water vapour.

In the third method the wire is dipped into the solution of barium salts, taken out and heated in carbon dioxide gas. This is repeated from fifty to one hundred times, and finally a layer of carbonate is formed. This layer is almost insoluble in water. The wire must be clean and the heating carefully carried out, or a "pearl-string" filament results. A filament made by this method is not vitiated by contact with the atmosphere.

The fourth method is done in vacuo. The core wire is oxidised before the evacuation of the bulb. On the side of the anode towards the filament a piece of barium metal is fixed. When a good vacuum is reached the anode is heated (usually by induction) and the metal evaporates. This vapour surrounds the filament, which is dull red, and tungstic oxide is reduced and barium oxide is formed. Barium azide solution can be painted on the anode instead of barium metal. The barium also acts as a getter after decomposition, although magnesium is usually employed as well.

With the first three methods pumping takes considerable time. The filament is heated to 900 deg. C. or 1,000 deg. C. without anode voltage and the anode heated. Activation commences as the vacuum improves and, as the filament improves in emissivity, it can be run cooler before sealing off. Ageing can then take place by heating the filament to its normal running temperature and applying an anode voltage. With the fourth method, the anode is heated in the same way, but the formation of the filament is more rapid and ageing is not always necessary.

If the coating is not uniform parts remote from the core are cooler than the more thinly coated parts, which give greater emission and produce "hot spots." This disadvantage is always present with this type of filament and is perhaps the reason why it has not been used with valves using very high anode voltages. Coatings of mixed oxides (*e.g.*, barium oxide and strontium oxide) and the use of thin coatings minimise this knot or pearl string formation.

With filaments made by the vapour process the thickness of the coating is under control, and measurements by the authors show it to be a few hundreds of molecules thick. Filaments by this process also show reasonably constant emission over long periods of life, and less variation from valve to valve. Fig. 2* shows this, the filaments "c" having been made by the vapour process,

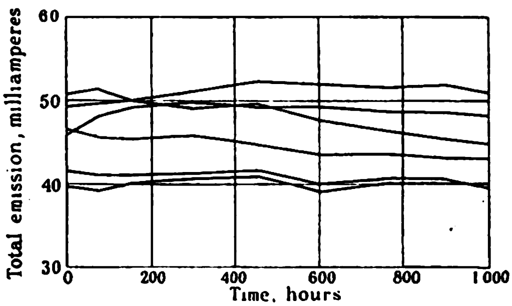


Fig 3.—*Variation of saturation current from an oxide-coated cathode made by the barium vapour process with life. Total emission of Mullard PM5 filament operated at 5.5 volts. Grid anode potential* 80 *volts. Grid connected to anode.*

while "a" and "b" were made by a paste process. Life curves of some valves made by the vapour process are shown in Fig. 3, while it is stated that the authors have not been able to detect any change in the amount of barium present in a filament after 1,000 hours' life.

Discussion.

In opening the lengthy discussion which followed the reading of the paper, MR. G. SHEARING said that

* The authors' original figure numbers are adhered to throughout this abstract.

the development of the oxide-coated filament was the most remarkable event of recent years in valve matters. Apart from their dull emitter properties, coated filaments had helped the study of the effects of gaseous content in the bulb. He suggested that the account given of the authors' own experimental work was too brief. As an example, he quoted the account of the use of barium and of barium-oxide filaments. What changes occurred in coated filaments if operated at excessive anode voltages, and was there any prospect of coated filament valves being available for greater power? On the subject of the value A (Table II), Dushman had shown that this varied according to whether the atoms of the surface layer were electropositive or electronegative. Lastly, he suggested that the incorporation of a bibliography would be helpful.

MR. M. THOMPSON said the authors had not given much information on the early history of the vapour process of filament coating. Table II showed the difficulties of studying oxide coatings. The work function ϕ for oxides displayed great discrepancies, showing the difficulty of measuring A. The value of 1 for ϕ with barium seemed to him unlikely. Caesium had a value of 1.4 and was more electropositive than barium, so he would expect barium to be higher. The theoretical value of 60.2 for A only applied to pure metals and had been proved for tungsten, molybdenum and thorium. He suggested the addition of the stroboscopic method of measuring small amounts of material in work on these filaments.

MR. P. K. TURNER asked several questions from the user's point of view. Could one express filament performance in terms of a ratio of mutual conductance to filament voltage for normal geometry of electrodes? What were the effects of running the valves at low emissions? As regards anode voltage were the working figures (given on valve boxes) based on specified limits in watts or were there higher safe limits to voltage? Were the filaments damaged by excessive anode current?

MR. HUGHES discussed the mechanism of emission. Only by knowledge of this subject would it be possible to build up a filament for higher powers. There was a need to know the mechanism of the separation of the barium.

MR. ROBINSON also spoke of the mechanism of emission. He suggested that the barium formation was possibly due to bombardment of the cathode by gas, *e.g.*, hydrogen or CO_2. The latter reduced readily when ionised. Discussing the adhesion of barium to the filament he suggested that the barium had under it a layer of oxygen. It was difficult to reconcile the authors' results with directly applied coatings and those of the vapour process. He considered the presence of strontium oxide also necessary.

MR. J. BEDFORD differed from the authors in their theory. He considered the statement of the effect of electrolysis misleading. Space current taken from the filament sets up a drift of ions due to dissociation. He did not agree with the authors' view of de-activation on running with no emission, but gave it as his experience that space current produced de-activation. The life curves given were interesting as differing from those obtainable with valves ordinarily purchased. He would be interested to know any reason. Why did the curves stop at 1,000 hours. He knew of coated filament valves going to 30,000 hours.

PROF. C. L. FORTESCUE thought that the position of thermionics was in a chaotic state. It had recently been stated that modern theories of wave mechanics could be used to explain thermionic theory, but he felt that physics had to go much further than at present to explain the actions involved.

MR. MCPHERSON asked if the life tests of Fig. 2 finished due to loss of activity. Coated filaments had been in use in valves of 300 watts dissipation at 1,600 v. and had been in existence for some time. At one broadcasting station such valves had given working lives of 3,000 hours.

The authors leaving the reply to the discussion to be communicated, the meeting terminated on a vote of thanks moved by the Chairman (Commander J. A. Slee, C.B.E.).

Abstracts and References.

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PROPAGATION OF WAVES.

RADIO ECHOES AND CONDITIONS FOR THEIR OCCURRENCE.—C. Stôrmer. (*Nature*, 5th January, 1929, V. 123, pp. 16-17.)

Since 24th October no more long-time echoes have been heard. It appears from this, and from the long silence in the spring and summer, that these echoes owe their occurrence to a series of favourable coincident circumstances. The mathematical theory shows that the chances of obtaining a well-defined toroidal space (January Abstracts) are good when the direction of the sun lies near the magnetic equatorial plane—confirmed by Birkeland's cathode ray and magnetised sphere experiment, a photograph of which is given showing the toroidal space. On the two occasions when the echoes were heard (October 11th and 24th) the sun was not far from this position. The writer suggests that the echoes will not be heard again till the middle of February, when this particular condition will be repeated.

ECHOS VON HERTZSCHEN WELLEN (Hertzian Wave Echoes).—K. W. Wagner. (*E.N.T.*, December, 1928, V. 5, p. 488.)

Discusses the Stôrmer-Hals echoes, and the short-time echoes of Taylor and Young, Hoag and Andrew (see recent Abstracts) and Quäck and Mögel (the observations of the last pair will appear shortly in *E.N.T.*). The short-time echoes, both American and German observers agree, come at intervals which are whole multiples of 0.010–0.011 sec., corresponding to path differences which are whole multiples of 3,000–3,300 km.

A VISUAL METHOD OF OBSERVING THE INFLUENCE OF ATMOSPHERIC CONDITIONS ON RADIO RECEPTION.—E. Merritt and W. E. Bostwick. (*Proc. Nat. Acad. Sci.*, November, 1928, V. 14, pp. 884–888.)

In studying fading and direction-shifts due to the combined effects of ground and sky waves, with a particular eye on the influence exerted by atmospheric conditions, it would be very desirable to find a method by which the effects of the sky wave (which is the more influenced by such conditions) could be measured by itself. The writers state that "thus far, no means of completely separating the two waves has been proposed. In fact, complete separation does not seem possible." They describe experiments in which a partial separation is effected by the use of two carefully balanced coil receivers, one (*a*) having its plane vertical and pointing towards the sending station, the other (*b*) with its plane vertical at right angles to this direction. (*a*) Responds to the resultant field due to ground wave and vertically polarised component of sky wave: (*b*) only responds to that component of the sky wave which is polarised with its electrical vector horizontal. It is not affected at all by the ground wave. The signals from (*a*) and (*b*) are heterodyned by one local oscillator: since the E.M.F. produced in the receiving circuit by this local oscillator is always greater than that due to either signal, the resulting amplitudes are proportional to those of the (*a*) and (*b*) signals. Moreover, the phase difference between the rectified beat-tones is the same as that between the original signals (U.S. Patent, No. 1,510,792, Merritt). These beat-notes, suitably magnified, are each brought to a pair of deflecting plates of a cathode ray oscillograph (*cf.* Friis, Abstracts, 1928, V. 5, p. 461), so that the vertical and horizontal movements of the spot of light correspond with the oscillations received on (*b*) and (*a*) respectively, both in amplitude and phase. So far the method has been used chiefly with different American broadcasting stations. The modulation (unless unusually strong) is rarely a source of disturbance. Tests with a similar short-wave apparatus, on American and European stations, show that code transmission gives no trouble, and that the absence of modulation gives particularly sharp and clear figures. The writers point out that as the arrangement gives only a partial separation of ground and sky waves, while there can be no vertical amplitude unless there is a sky wave, the absence of vertical amplitude does not necessarily mean that no sky wave is present, for it might be unsuitably polarised. The character of the figures produced is described: the changes as sunset approaches and the sky wave begins to appear: occasional continuous rotation shortly after sunset (as many as 20 complete turns, in the same sense, have been counted in a few minutes)—probably due to the rapid rise of the Heaviside layer producing a progressive change in phase and a progressive rotation of plane of polarisation. At night, both waves appear to be modulated equally, but when a strong sky wave is present in the day (*e.g.*, late afternoon) its modulation is much less marked than that of the ground wave. At night the movements of the figure are quite erratic: rotation, when it occurs, is sometimes in one sense and sometimes in the other: changes are in general more rapid than by day, but occasionally circular polarisation persists with unchanged amplitude for as long as two minutes. Observations during an auroral display are described: the figure showed violent and erratic changes so rapid that they could be followed with difficulty. This period of disturbance was preceded (about an hour earlier) by one of rapid changes and of rotations (some lasting two minutes) in both senses; but the time of beginning of the aurora is not known, and it is not quite clear whether these effects were more marked than usual. It is, however, mentioned that until they began, and for some days previously, "conditions for radio reception had been unfavourable," and only weak sky waves, and slow and not marked changes in figure, were observed.

SOME NOTES ON WIRELESS METHODS OF INVESTIGATING THE ELECTRICAL STRUCTURE OF THE UPPER ATMOSPHERE. Part I.—E. V. Appleton. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part 1, pp. 43–59.)

This is the U.R.S.I. paper referred to in the abstract (February, 1929, p. 98) of an *E.W. & W.E.* editorial. In addition to the comparison of the three methods of determining the effective height of the layer, referred to in that abstract, the paper deals with methods of investigating the ionisation gradient (*a*) by height measurements on a number of mean frequencies at about the same time and under the same conditions of transmission distance, etc.; and (*b*) by simultaneous observations on the same mean frequency, at different distances; additional evidence being obtained by comparing results on different frequencies. (*Cf.* Schelling, February Abstracts.) In the subsequent discussion, Hollingworth states that his experience (on very long waves) suggests that for long distances of transmission the path is of a "flat-topped" form rather than triangular, and that the angle (with vertical) of incidence at the layer is definitely greater than 30 deg. (which point is welcomed by the author as an indication that the first method of finding the ionisation gradient may be carried out with some hope of success). Replying to Eccles, the author remarks that although the paper is based on the ionic refraction theory, it may turn out that the ionisation gradient is greater than commonly supposed and that we shall have to replace simple ionic refraction by some process intermediate between such refraction and true reflection. If, in such a case, the boundary of the layer had a certain degree of "roughness," we could possibly explain "skipped distances" as being regions in which only diffusely reflected radiation is received, the specularly reflected radiation being received at greater distances. [Contrast this with Ponte and Rocard, February Abstracts.] Such an explanation would give the correct relation between the wavelength and the magnitude of the skipped distance. Rankine points out the apparent close, but inverted, analogy between the travelling of wireless waves in a "flat-topped" path and the behaviour of seismic phenomena (natural earthquakes and artificial surface explosions), where the disturbances travel more rapidly in the deeper strata than in those near the surface. T. Smith, by optical reasoning, points out the difficulty of contriving experiments which really measure $\int \mu ds$; almost any procedure turns into one which deals with $\int ds/\mu$ rather than with $\int \mu ds$; for instance, a *signal* of any kind must give $\int ds/\mu$, for a signal is given by imposing a peculiarity of some kind on a train of waves, that is to say, it concerns group velocity, not phase velocity. In optics $\int \mu ds$ would probably be evaluated by an interference method, preferably one in which "white light fringes" were obtained. Perhaps a corresponding method, in which the time taken by an interfering wave to travel between source and receiver can be controlled and adjusted to give steady agreement of phase with the reflected beam for a range of wavelengths, would be possible in the wireless problem. He also points out that $\int ds/\mu$, besides being related to the length of hypothetical rectilinear paths observed from the ground (as the author showed), can be related to the area enclosed by the wave in its actual path.

ÜBER TELEGRAPHIE MIT KURZEN WELLEN (Short Wave Telegraphy).—H. Rukop. (*E.T.Z.*, 13th December, 1928, p. 1815.)

Abstract of lecture to the 1928 Hamburg Meeting of German scientists. A survey of our present knowledge as to the use of waves of 10–50 m. length. The limiting lengths, beyond which there is no return from the Heaviside layer, are by day 9–10 m. and 50–100 m.; by night the lower limit changes to about 18 m. Measurements by various methods allow us to place the height of the layer between 60 and 200 km. By a suitable choice of wavelength for each particular line of communication and for each time of day, a faultless commercial service can be obtained with piezo-electrically controlled valve transmitters giving up to 120 words per minute.

ÜBER DIE AUSBREITUNG KURZER ELEKTROMAGNETISCHER WELLEN IN DER HEAVISIDESCHICHT (Propagation of Short Waves in the Heaviside Layer).—K. Försterling. (*E.N.T.*, December, 1928, V. 5, pp. 530–542.)

Although this paper was only sent for publication in June, 1928, it is labelled as having been read at the Heinrich-Hertz Society in Berlin in September, 1927. The author accepts the arguments of Lassen (based on Lenard's tests) that the ultra-violet solar radiation is alone responsible for the ionisation of the atmosphere. He considers (1) refraction and absorption of waves in a layer containing free electrons or ions, and the effect of temperature; (2) propagation in a medium such as that of the layer: reflection; (3) reflection at a layer of finite thickness: improbability of a sharp border surface above or below: probability of the gradual change of condition of the atmosphere with increasing height, so that the refractive-index changes very little within the length of a wave; (4) propagation of light in an inhomogeneous medium, and the analogous behaviour of wireless waves: "at a medium of slowly changing dielectric constant there is either no reflection at all or total reflection. . . . Since within the layer the square of the refractive-index has a minimum, the condition (for total reflection) is fulfilled either not at all or twice": in the latter case there are two planes at which total reflection takes place, at a distance D ("effective thickness") dependent on the wavelength and on the earth-angle: the greater this thickness, the stronger the reflected wave. This section ends with a suggestion of the differing effects of a wave-front reflected and a wave-front bent by refraction: the relative positions of points on the front, on leaving and on returning to earth, are unchanged in the first case but reversed in the second: "the second case is impossible so long as the refractive-index depends on one co-ordinate and obeys the refraction law, since according to this parallel rays remain parallel the whole length of their path"; (5) the effect of

the earth's magnetic field: "for very short waves the magnetic influence is very slight. . . . There is a critical frequency $\omega_0 = \frac{eH_0}{cm}$ near which the influence of the magnetic field becomes very marked. For free electrons this critical wavelength is about 210 m. For ions it is about 2,000 times greater." Although there may be relatively few free electrons compared with the mass of ions in the layer, it is likely that the propagation of waves in the neighbourhood of 210 m. is subject to certain peculiarities.

APPLICATION TO GEOPHYSICAL INVESTIGATIONS OF LEVI-CIVITÀ'S THEORY RELATING TO THE INFLUENCE OF A CONDUCTING SCREEN ON THE ELECTROMAGNETIC FIELD OF AN ALTERNATING CURRENT PARALLEL TO THE SCREEN. —A. Rostagni. (*Nature*, 29th December, 1928, V. 122, p. 1018.)

Title only of a paper read before the Royal Nat. Acad. Lincei, 17th June, 1928.

SUR LES PROPRIÉTÉS DES GAZ IONISÉS DANS LES CHAMPS DE HAUTE FRÉQUENCE (The Properties of Ionised Gases in H.F. Fields).—H. Gutton. (*Comptes Rendus*, 7th January, 1929, V. 188, pp. 156–157.)

The writer's previous work showed the existence of a natural period of oscillation for the ions; the present paper describes more experiments, to test how the elastic force varies with the conductivity of the gas. Measurements of the ionisation corresponding to resonance were made with four values of wavelength ranging from 1.324 m. to 4.830 m. Results showed that the product $\lambda^2 i^{0.75}$ was a constant (i being the current measuring the degree of conductivity); therefore, as the conductivity is proportional to the number of ions per c.c., the elastic force is proportional to the 0.75 power of this number.

NOTE SUR LES EXPÉRIENCES RELATIVES AUX PROPRIÉTÉS DIÉLECTRIQUES DES GAZ IONISÉS DE MM. GUTTON ET CLÉMENT (Note on Gutton and Clément's Experiments on the Dielectric Properties of Ionised Gases).—J. Rybner. (*L'Onde Élec.*, October 1928, pp. 428–436.)

Gutton and Clément have explained their results on the hypothesis that the ions are not free, their movements taking place under quasi-elastic forces (Abstracts, 1927, p. 572; 1928, p. 222, and above). The present writer explains the results on the classic idea of free ions; reconciles them approximately with Pedersen's formulæ, and suggests that with certain modifications the experiments would give a basis for exact calculations giving valuable information on the average speed of electrons in an ionised gas. His main point is to prove that large decrements are not necessary to explain the variations of the frequency of resonance; and that the contrary is even true.

THE MOBILITY OF IONS IN AIR. Parts IV and V. —A. M. Tyndall, L. H. Starr and C. F. Powell; A. M. Tyndall, G. C. Grindley and P. A. Sheppard. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121 A., pp. 172–194.)

Two new methods of measuring the mobility, both of which have a high resolving power, are described. The apparatus can be made airtight, and the ions can be given any required age (from 1/65 to 2/3 sec.) before their mobility is measured. A third (air-blast) method is described which was used to check previous results. A number of conclusions are drawn from the experiments: among these may be mentioned the marked increase in the rate of transformation produced by a small quantity of ozone; at long ages the positive ions in air have mobilities distributed over a small range with a mean value of about 1.25, and this mobility is independent of the humidity of the air; there is no evidence of initial positive ions in very dry air or in pure nitrogen. If any are formed, they nearly all transform in less than 1/100 sec.

ON THE RATE AT WHICH PARTICLES TAKE UP RANDOM VELOCITIES FROM ENCOUNTERS ACCORDING TO THE INVERSE SQUARE LAW. —L. H. Thomas. (*Proc. Roy. Soc.*, 1st November, 1928, V. 121 A., pp. 464–475.)

Author's Summary:—The formulæ obtained—for low densities—lead to "effective mean free paths" shorter than might have been expected. It seems not impossible that the rapid rate at which beams of electrons moving through highly ionised gases have been observed by Langmuir to take up Maxwellian velocity distributions may be explained in this way.

DIAGRAMME DES CHAMPS ÉLECTRIQUES MESURÉS À MEUDON PENDANT LE DEUXIÈME SEMESTRE 1927 (Diagram of the Electric Fields measured at Meudon during the second half of 1927).—(*L'Onde Élec.*, October, 1928, pp. 458–460.)

These diagrams record the fields in microvolts per metre for Bordeaux, Nantes, Rocky Point and Leafield. References are given to 13 previous sets published in the same journal since 1922.

ÜBER DIE FORTPFLANZUNGSGESCHWINDIGKEIT ELEKTRISCHER WELLEN AN DÜNNEN DRÄHTEN VON VERSCHIEDENEM LEITVERMÖGEN (The Velocity of Propagation of Electric Waves along thin Wires of various Conductivities). —L. Bergmann and G. Holzlöhner. (*Ann. d. Physik*, 1st November, 1928, V. 87, No. 5, pp. 653–676.)

The variation with the radius and the conductivity is experimentally investigated, on wavelengths 172 and 400 cm., for copper, aluminium, manganese, etc. Diameters varied from 0.04 to 0.3 mm. Results agree well with the theory described at the beginning of the paper.

FIELD STRENGTHS OF EUROPEAN BROADCASTING STATIONS MEASURED AT BERLIN.—M. v. Ardenne. (*See under* "Measurements and Standards.")

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

ON THE ORIGIN OF THE AURORA POLARIS.—S. Chapman, with reply by E. O. Hulburt. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 993–996.)

Hulburt's new theory is criticised on the ground, principally, that free high-atmospheric ions in middle and low latitudes cannot travel far towards the poles along the earth's lines of magnetic force, because they must at the same time descend into the lower levels where their motion is interrupted by collisions. Upward moving ions will travel towards the equator. Hulburt replies that the ion spray caused by the sun's ultraviolet light may reach heights of (say) 30,000 km. above the equator, and may distil to within 20–30 deg. from the magnetic poles rapidly enough to supply the energy of the aurora. *Cf.* February Abstracts.

POTENTIAL GRADIENT AT GREAT HEIGHTS.—P. Idrac. (*Nature*, 29th December, 1928, V. 122, p. 1013.)

Summary of a publication by the French Meteorological Office, amplifying the 1926 paper by Idrac. A balloon carries the (valve) electrograph and the barothermograph. According to the afternoon averages, the gradient over Trappes at 2 km. is 43 V/m.; at 5 km. this falls off to 11, but at 7 km. it is 25 and at 9 km. it rises to 30. There is then a sudden drop, presumably on entering the stratosphere, to 2 V/m.; another rise begins at 12½ km. up to a max. of 16 V/m. at 14 km. "The diminution to practically zero gradient at 20 km. seems to be based on one record only." "If we may interpret the observations in the light of Coulomb's Law it appears that in the afternoon the air is positively charged up to 5 km., negatively between 5 and 9 km. There is a considerable positive charge just below the stratosphere. The stratification by night and in the morning is found to be somewhat simpler."

MESSUNGEN DER DURCH ELEKTRONENSTRAHLEN VERURSACHTEN IONISATION DER LUFT (Measurements of Air Ionisation by Electron rays).—W. Schmitz. (*Physik. Zeitschr.*, 15th November, 1928, pp. 846–849.)

For electron speeds of from 1,000–10,000 V., the mean volt-energy needed for the formation of an ion-pair keeps almost constant at about 42 V.

DIE MITTLERE LEBENSDAUER DER IONEN IN DER LUFT ÜBER DEM MEERE (The Mean Life of Ions in the Air over the Sea).—V. F. Hess. (*Physik. Zeitschr.*, 15th November, 1928, pp. 849–851.)

Results of recent tests in Heligoland. With a N. or N.N.W. wind, the light ion life is 200–300 sec. Condensation nuclei are only 500–1,500/c.c. With wind from the land (S.) these numbers may become about 30 sec. and 10,000/c.c. respectively.

THE EFFECT OF WATER VAPOUR ON THE MOBILITY OF GASEOUS IONS IN AIR.—H. A. Erikson. (*Phys. Review*, November, 1928, V. 32, pp. 791–794.)

Supplement to a 1927 paper. The H_2O molecule gives up an electron to the final positive air ion and thus forms an H_2O+ ion of a greater mobility. The reciprocal of the mobility bears a linear relation to the humidity.

ÜBER DEN EINFLUSS DER TEMPERATUR AUF DIE ZUSAMMENSETZUNG DER ATMOSPHÄRE IN DEN OBERSTEN SCHICHTEN (The Influence of Temperature on the Composition of the Highest Layers of the Atmosphere).—H. Petersen. (*Physik. Zeitschr.*, 1st December, 1928, pp. 879–884.)

Working on the assumption of a condition of equilibrium of flow instead of the usual static equilibrium of diffusion, the writer finds that the amount of helium in the atmosphere decreases with height far more rapidly than it would according to the latter idea; this fits in with the Northern Light spectrum. The possibility is also discussed—and shown to exist—of the destruction of the helium molecules by the corpuscular streams from the sun.

ERGEBNISSE MEINER UNTERSUCHUNGEN DER MESSUNGEN DES ERDPOTENTIALS (Results of my Investigations into the Measurements of Earth Potential).—R. Stoppel. (*Vortragshandbuch*, 90. *Versamm. d. Ges. deut. Natur. forsch.*, Hamburg, September, 1928.)

The summary contains the statement that the earth's charge is regarded as constant, but that this is not the case when limited areas of the earth's surface are dealt with. Preliminary results from the author's method of measuring these local variations show that at night the earth takes on a more negative charge, by day a more positive; and that the extremes of the curve fall at about midnight and midday.

TRIBO-ELECTRICITY AND FRICTION. IV.—ELECTRICITY DUE TO AIR BLOWN PARTICLES.—P. E. Shaw. (*Proc. Roy. Soc.*, 1st January, 1929, V. 122A, pp. 49–58.)

The impact of two unlike metals, of two like metals, or of sand on sand or ice on ice, is studied by driving wind-blown particles of these materials on to surfaces of one material only; the charges arising on the particles, surfaces and issuing air are separately measured. Results show that the Volta-effect plays a large, but not exclusive, part in the genesis of the charges; when the particles and surfaces are chemically identical, considerable charges arise. The results for sand and ice provide a key to the meteorological effects observed in electric sand-storms and snow-storms.

THE ELECTRIFICATION OF AIR BY FRICTION.—A. W. McDiarmid. (*Phil. Mag.*, December, 1928, V. 6, pp. 1132-1140.)

Experiments are described with the object of

discovering whether or not electrification can result from the friction of dry, dust-free air with solid surfaces. They show that the passage of a rapid current of such air through a tube causes the current to carry with it charged particles of air and leaves the tube oppositely charged. It is thought that the need for a quick flow is due to secondary effects, *e.g.*, it may be necessary to prevent the charges on the air and on the tube from recombining and so masking the effect.

EVALUATION OF THE TRUE INFLUENCE OF THE ELECTRIC HYPER-ATMOSPHERE ON TERRESTRIAL MAGNETISM.—D. A. Grave. (*C.R., Academy of Sciences*, Leningrad, No. 22, 1928.)

The same number contains a paper by Kravetz on Magnetic Anomalies, in which he discusses a previous paper by D. A. Grave and says that his arguments are based on a misunderstanding.

PROPERTIES OF CIRCUITS.

ÉQUILIBRES INSTABLES ET RÉGIMES STATIQUES PARASITES DANS LES CIRCUITS ÉLECTRIQUES ASSOCIÉS AUX TRIODES (Conditions of unstable equilibrium and of parasitic disturbances in electric circuits associated with 3-electrode valves).—I. Podliasky. (*L'Onde Élec.*, November, 1928, pp. 475–487.)

Conclusion of the paper referred to in Abstracts, 1928, V. 5, p. 580. It begins by completing the first instalment's treatment of dynatrons and other valves used in such circuits that secondary emission is predominant: "the condition of parasitic disturbance is only possible if the internal characteristic possesses points of inversion of plate current: *i.e.*, if a value of plate voltage exists beyond which the secondary (plate) emission dominates the primary (filament) emission." Various ways of avoiding these—sometimes very destructive—disturbances are discussed; diminution of the external resistance below the critical value—not always possible; lowering the grid voltage; decrease of filament temperature—this will always suppress the points of inversion. (An increase, on the other hand, does not always have the opposite effect; some valves only allow parasitic conditions between two limits—often quite close—of filament temperature.) The paper then passes on to similar effects in ordinary triode circuits where the anode is positive to the mean grid voltage, and secondary emission from the plate does not occur. What can occur, however, is secondary emission from the grid, even where the grid is negatively polarised; and this can produce parasitic conditions analogous to the ones previously dealt with, and equally or more destructive. Their study is very difficult, for they start spontaneously and quickly destroy the valve. The condition is indicated by a high anode current, together with a small grid current in the reverse direction to normal. It is thus easily confused with the parasitic condition due to ionisation of the residual gas; but the difference can be made evident if the valve is robust enough to survive, for the electron disturbance is perfectly stable, whereas the ionic effect fluctuates. The latter is accompanied by blue glow; but the matter is complicated by the fact that in power valves (particularly water-cooled) the electron effect often starts by itself and then, by heating the electrodes, sets free occluded gases and starts the ionisation effect. These conditions of parasitic disturbance are particularly dangerous to thoriated filaments, which disintegrate rapidly during the period of reverse grid current. The paper then returns to methods of protection: choice of triodes with suitable grid characteristics; avoidance of surges by applying the anode voltage very gradually, short-circuiting meanwhile the grid resistances; or by introducing into the anode feed "anti-shock" coils (Bethenod suggests self-inductances shunted by high resistances). Filament regulation (previously referred to) is rarely possible, as it usually reduces the power too much; so does reduction of anode voltage. The writer advocates the use of a permanent magnetic field—taking advantage of the greater deflection of the (slower) secondary electrons. A suitable field completely removes the possibility of these disturbances, and appears even to increase the useful power of the valve—thanks to the greater constancy of the saturation current. In some high-power valves, the field created by the filament-current is enough to sweep away the secondary emission. Another plan (Philips Lamp Co.) introduces a diode in the grid circuit and thus prevents reversal of grid current; another (Shaposhnikow) neutralises the reverse grid current by a current through a diode shunted between grid and filament.

ÜBER ELEKTRISCHE SCHWINGUNGEN IN ZUSAMMENGESETZTEN KREISEN UND ÜBER DIE KAPAZITÄTSMESSUNG VON WIDERSTÄNDEN UND SPULEN NACH DER RESONANZMETHODE (Oscillations in compound Circuits, and the Capacity Measurement of Resistances and Coils by the Resonance Method).—M. Jezewski. (*Zeitschr. f. Phys.*, 5th April, 1928, V. 48, pp. 123–136.)

Earlier investigations (*ibid.*, V. 43, 1927, p. 442), of an oscillating circuit with resistance in parallel with the condenser, are here amplified; also, the oscillations in a circuit with a coil in parallel with the condenser are investigated. Formulæ for voltage and current are derived, and the procedure for the capacity-measurement of resistances and coils is described.

ÜBER MAXIMALLEISTUNGEN VON VERSTÄRKERRÖHREN (The Maximum Power Output of Amplifier Valves).—A. Forstmann and E. Schramm. (*Zeitschr. f. Hochf. Tech.*, December, 1928, V. 32, pp. 195–199.)

Paying attention to the straight line conditions, the optimum values are determined for the external load-resistance, to produce maximum power output for a given anode voltage. The conditions as to steepness of characteristic and the amplification constant (or its reciprocal) are also considered.

A GENERALISED ANALYSIS OF THE TRIODE VALVE EQUIVALENT NETWORK.—F. M. Colebrook. (*Journ. I.E.E.*, January, 1929, V. 67, pp. 157–169.)

Author's summary :—

The paper gives an analysis of the variation with the resultant anode circuit load of the input impedance and voltage magnification factor of a triode valve. A new mode of presentation is adopted which enables the total range of variation of these quantities to be represented as finite functions of a variable with a limited range of variation.

The most important conclusion is that at very high radio frequencies the voltage magnification factor may appreciably exceed the voltage factor of the valve, this condition being reached for a finite pure inductive load. Under the same conditions, however, the shunt input impedance is very low.

The most efficient means of associating a tuned circuit with a receiver of relatively low input impedance is considered in an Appendix.

ÉTABLISSEMENT DU COURANT DANS UNE SÉRIE DE CIRCUITS RÉSONNANTS COUPLÉS ENTRE EUX PAR L'INTERMÉDIAIRE DE LAMPES TRIODES (Calculation of the Current in a Series of Resonant Circuits coupled by 3-Electrode Valves).—G. Fayard. (*Bull. d.l. Soc. Fr. Rad.*, October, 1928, pp. 3–7.)

Derivation, by simple reasoning of the general expression for the amplitude in the p^{th}, namely :

$$1 - e^{-\frac{\pi}{s}.n}\left[1 + \frac{\pi}{s}.n + \left(\frac{\pi}{s}.n\right)^2.\frac{1}{2!} + \ldots\ldots\left(\frac{\pi}{s}.n\right)^{p-1}.\frac{1}{(p-1)!}\right].$$

REGENERATIVE COUPLING DEVICES IN AUDIO AMPLIFIERS.—J. K. Clapp. (*QST*, December, 1928, pp. 37–39.)

Applications : heterodyne reception of telegraphy : eliminating harmonic frequencies from a low power source, as used for bridge measurements : in various control problems, for selection of a desired operation.

HIGH FREQUENCY RESISTANCE : WHAT IT IS AND WHENCE IT COMES : LOSS OF ENERGY DUE TO DIELECTRIC.—A. L. M. Sowerby. (*Wireless World*, 19th and 26th December, 1928, V. 23, pp. 810–814 and 845–849.)

TRANSMISSION.

SUR LES OSCILLATEURS À ONDES TRÈS COURTES (Oscillators for Very Short Waves).—E. Pierret. (*Comptes Rendus*, 10th December, 1928, V. 187, pp. 1132–1134.)

An extension of the work referred to in Abstracts, 1928, V. 5, pp. 402 and 465. With the particular arrangement used, there is always a certain grid voltage below which only Barkhausen oscillations can be obtained, and another (higher) voltage above which only the much shorter waves appear, whatever the anode voltage may be : between these critical voltages, whether the Barkhausen or the short waves are obtained depends on the anode voltage. Various tuning effects are described, confirming the writer's former idea that whereas in the Barkhausen oscillations (in the region 40–70 cm.) the electrons oscillate between grid and plate, these very short waves (12–18 cm.) are caused by an oscillation of electrons from one part of the grid to another ; in the former case, the frequency of the oscillations produced in the antennæ is the same as that of the electronic oscillations, whereas in the latter case it is double that frequency. The writer's circuit consists of a horned valve, the grid and plate of which are attached each to one end of a copper rod on which a copper disc slides which reflects the waves and allows of tuning : the opposite ends being connected to the batteries of accumulators charging the electrodes.

SUR LES ONDES TRÈS COURTES (Very Short Waves).—G. A. Beauvais. (*Comptes Rendus*, 26th December, 1928, V. 187, pp. 1288–1289.)

Describes experiments with waves of 16–20 cm. length generated by Pierret's method (see above) and received by an arrangement similar but with lower grid voltage (about 100 v.) and a colder filament : a telephone being connected in the filament-plate circuit. The presence of stationary waves (by reflection at a metallic screen) is easily shown with this receiver. Reflection, by more than one mirror, was obtained according to optical laws. Telephony was worked successfully : the grid feed was through an iron-cored choke of some henries, and a three-electrode modulator valve (with the usual microphone transformer, etc.) had its anode connected to the grid of the oscillator. The receiver described above was improved by the use of super-regeneration : the grid of the valve was supplied with a D.C. voltage of 250 v. on which was superimposed the A.C. tension due to a H.F. oscillator : filament temperature was slightly raised, and a suitable negative voltage was supplied to polarise the anode. Range for the tonic train or I.C.W. waves used in the first experiments was increased " considerably " ; it is not clear whether the newer receiver was used for telephony, nor is the range given.

SHORT WAVE GENERATION WITH A QUARTZ OSCILLATOR.—(*French Patent No.* 642,969, Soc. Radiofrequenz and H. Eberhard, pub. 7th September, 1928.)

A three-electrode valve circuit is described in which the filament-anode circuit consists of the anode battery, a large inductance and a small inductance in series : at the point of junction of these two inductances a lead goes to a quartz oscillator and thence to the grid. When the natural frequency of the small inductance approaches that of the quartz oscillator, oscillations are set up, the wavelength being of the order of a few metres.

REICHWEITENVERSUCHE UND DÄMPFUNGSMESSUNGEN IM GEBIET SEHR KURZER WELLEN (Range Tests and Damping Measurements for Very Short Waves).—A. Esau. (*Summary in E.T.Z.*, 13th December, 1928, p. 1816.)

The decrement was measured on a wire loop whose ends were connected to two condenser plates of variable gap. A detector and galvanometer were connected to the point of symmetry. With $\lambda = 3$ m. and a loop of 240 cm.^{2} surface and 2.5 cm. condenser gap, the decrement was 0.032 and the radiation resistance 2.4 ohms. Increasing the condenser gap increased the radiation resistance. With these short waves the condenser itself radiates. The large condenser gaps will be useful for medical purposes. Waves down to ¾-metre were tested. Range is unaffected by atmospheric disturbances and fading. No difference in propagation could be noticed between 1.5 m. and 6 m. waves. Intensity fell off slowly but uniformly in all directions. No re-appearance from the Heaviside layer was noted. The use of such waves on trains is suggested, for communications between engine and rear of train: but there still remains the problem of the tunnel (*cf.* Ritz, these Abstracts). A transmitter on an aeroplane, using 0.1 W. (to aerial?), was heard at a height of 1,000 m. and at a distance of 35 km. at loud-speaker strength. Picture telegraphy is another suitable field.

ESSAIS SUR ONDES TRÈS COURTES (Trials on Very Short Waves).— —. Ritz. (*L'Onde Élec.*, November, 1928, pp. 488–499.)

Description of tests on portable tonic train sets, on a wavelength of 3.3 metres, made in mountainous country where the configuration of the ground enabled all kinds of conditions to be tried: with the idea of confirming and extending the results of Mesny (Abstracts, 1928, V. 5, p. 687). The sets are first described (Symmetrical Mesny transmitting-receiving circuit, 5-valve: transmitter feed about 15 mA. at 80 v.; total weight per set, including telescopic brass antenna and counterpoise, about 30 lb.). Results are summed up by the remark that the neighbourhood of earth is fatal to these waves; they will only fly into the distance if they can escape quickly and completely from its influence. Tests are described: (1) In a tunnel (circular absorption): one set 20 m. from the tunnel-mouth, the other moving into the tunnel; signals fall to R3 at 60 metres, and disappear at 75 m.; with both sets inside the tunnel, R3 at 100 m., zero at 125 m. (2) In a gorge (absorption on three sides): signals are extinguished by bends in the gorge. These and many other tests all confirm Mesny's results.

MODULATION DANS LE CIRCUIT DE PLAQUE (Anode-circuit Modulation).—J. Marcot. (*QST Franç.*, November, 1928, pp. 43–46.)

Of the various anode-circuit control methods, that of Heising has the advantage of giving very pure modulation even when the control is great. This article gives a mathematical analysis of the circuit.

MEASUREMENT OF MODULATION.—(*German Patent No.* 465,040, Schäffer, pub. 7th September, 1928.)

A glow discharge lamp is so coupled to the aerial that with a certain depth of modulation the voltage is enough to start the glow. But, once started, the glow extinguishes itself too slowly; according to the invention, the circuit containing the lamp is thrown in and out of tune (by a motor-driven rotating condenser) with a frequency low in comparison with the modulation frequencies; this ensures the periodic extinction of the glow.

ÜBER DEN EINFLUSS DES PHASENMASSES UND DER DÄMPFUNG BEI DER ÜBERTRAGUNG VON MODULIERTEN WELLEN (The Influence of Phase Relations and Damping on the Transmission of Modulated Waves).—H. Bartels. (*Wiss. Veroff. a.d. Siemens-Konz.*, No. 1, 1928, V. 7, pp. 260–272.)

Under certain conditions, interference between the two sidebands may make it better to use only the one. For carrier frequency telegraphy it is usually best to employ the two bands, for carrier frequency telephony it is often best to use only the one.

ADAPTING MEDIUM AND HIGH-POWERED SELF-EXCITED TRANSMITTERS FOR 1929 SERVICE.—R. A. Hull. (*QST*, September, 1928, V. 12, pp. 25–30.)

Two points particularly stressed are: Low or high values of grid excitation require extremely loose antenna coupling to give satisfactory frequency stability, whereas with grid excitation of a particular order, the normal coupling can be used and high efficiencies obtained; the amateur transmitter can be tuned about as successfully by watching the meters alone as an automobile can be driven in heavy traffic by exclusive observance of the ammeter and the oil gauge; tuning (and operation) *must* be controlled by listening on a check circuit (preferably crystal controlled).

THE OSCILLATOR-AMPLIFIER TRANSMITTER.—R. A. Hull. (*QST*, September, 1928, V. 12, pp. 9–14.)

Description of a master-oscillator-amplifier transmitter for wavelengths of about 42 m., to give very clean and steady signals; it can be left running with automatic keying for two hours on end without a serious frequency drift; plate voltage can be varied 10 per cent. with only just observable frequency change. As there is no crystal control, the required constancy can only be obtained if the input to the oscillator is at least one-sixth of the amplifier input and if the oscillator is run well below its rating.

A 28-MEGACYCLE CRYSTAL-CONTROLLED TRANSMITTER.—H. A. Chinn. (*QST*, November, 1928, V. 12, pp. 29–32.)

"Frequency was known to be 28 megacycles, within 0.1 of 1 per cent. This article, describing the transmitter used, is presented not because of any new or radically different features involved but

rather to show the straightforward arrangement. ." The crystal has a fundamental frequency of 1.75 megacycles, so that four frequency doublers are necessary. The last stage contains two 2,000 v. valves in parallel; these originally formed the last stage of frequency doubling, but it was found that by using them as straight amplifiers (with neutralisation) and adding one more 200 v. valve as frequency doubler (the final doubler being a 500 v. valve), the output was increased many times with the same input. Valves used as frequency doublers are working less efficiently.

PUSH PULL TRANSMITTERS.—J. J. Lamb. (*QST*, December, 1928, pp. 13–16, 82 and 88.)

" . . . it is particularly recommended that those transmitters in which two tubes are being used in parallel may be converted to the push-pull circuit in one form or another to good advantage."

THE CONSTRUCTION AND OPERATION OF A 3,500-KC. CRYSTAL-CONTROLLED PHONE.—E. W. Springer. (*QST*, December, 1928, V. 12, pp. 9–12.)

Modulation is by the Heising constant current system, either the crystal oscillator or the amplifier being thus controlled. Tests for the adjustment of the set are described; when these had been fulfilled, reports from distant stations showed very good or perfect modulation; and when received on zero beat tuning, reception was practically as clear as when the receiver was not oscillating—showing great steadiness of frequency.

RECEPTION.

LE RÉGLAGE DES POSTES RÉCEPTEURS RADIOÉLECTRIQUES, ET LE NOUVEAU DISPOSITIF DE RÉGLAGE "VALUNDIA" (The Adjustment of Radioelectric Receivers, and the New "Valundia" Scheme of Adjustment). —J. L. Routin. (*Rev. Gén. d. l'Élec.*, 29th December, 1928, V. 24, pp. 987–989.)

A complete unit of calibrated adjustment much employed in French superheterodyne receivers is here described and illustrated. The indicating part includes two drums side by side, each rotated by its own geared button: each drum serves not only as a chart on which calibration curves are traced, but also as housing for the moving plates as a condenser. A fixed scale of wavelengths is situated in front of the two drums, and the complete adjustment is obtained by turning the two buttons so that each calibration curve cuts the scale at the required wavelength. A change-over switch is embodied in the unit which not only switches the apparatus from "long" to "short" waves, but at the same time rotates the fixed scale so that the appropriate graduations appear.

THE DIODE RECTIFIER.—H. L. Kirke. (*Wireless World*, 9th January, 1929, V. 24, pp. 32–35.)

The Editorial summary says: "This article, by the originator of the 'space charge neutralised' diode detector, explains the precautions that must be taken in order to obtain perfectly distortionless rectification. An interesting new B.B.C. long-range, high-quality receiver is also described." A history of the development of the circuit and its original particular object is first given; later, interesting points are: the use of a pentode as the preceding valve—on 100 v. H.T., it appears to work very well; a 3-electrode valve in this position would require careful neutralisation, while the ordinary type of screen-grid valve has insufficient linear power output: the advantage of the diode being independent of the high-tension supply (*cf.* H. F. Smith, Abstracts, February, 1929) should be used to the full (especially where mains units are employed) by making the output stage a push-pull one, in which the audio-frequency currents do not necessarily have to pass through the high-tension supply system: the disadvantage of the considerable current demanded from the grid polarising battery (20 mA. at 24 v. for large inputs) —high capacity electrolytic condensers withstanding a working potential round 40 v. will, when procurable, assist in the obtaining of grid-polarising potential from the mains, which at present offers certain difficulties: a low L/C value for the tuned circuit, though rather inconvenient, is more satisfactory than the tapped-down inductance suggested in the above-named article, probably because the former provides a low impedance path for the harmonics produced. There is an editorial, in the same issue, on the subject of diode detection; its conclusion is "it would hardly appear to be strictly necessary to include diode detection except in cases where no expense or trouble is spared to avoid distortion at each and every stage of the receiver." There is a letter (*ibid.*, 16th January) from the G.E.C., pointing out the drain put on a filament designed for a maximum anode current of say 5–6 mA. is used in this way to give perhaps 20–30 mA., so that the choice of a suitable valve should be made carefully: and also correcting any idea that "the normal grid bias battery, reversed, could always be employed for the diode detector circuit."

DIODE RECTIFIER.—P. G. Davidson. (*Wireless World*, 2nd January, 1929, V. 24, p. 23.)

A letter suggesting an arrangement of two "matched" valves, to give a performance superior to that of the diode recommended by Smith (February Abstracts): linear rectification for A.C. inputs between zero and a peak voltage equal to the grid bias: sensitivity comparable with that of an anode-bend rectifier having an anode resistance equal to that of the valve under rectifying conditions, *i.e.*, several times the normal valve resistance: applies no damping to the preceding tuned circuit.

UN RELAIS-AMPLIFICATEUR POUR ONDES COURTES (A Relay-Amplifier for Short Waves).—J. Vivié. (*QSTFranç.*, November, 1928, pp. 21–24.)

The waves considered are from 100 m. down to 10 m. The circuit consists in a combination of a screen-grid H.F. amplifier valve and the so-called "Schnell" triode circuit with electrostatic reaction coupling.

THE PENTODE AND POWER AMPLIFICATION: SOME IMPORTANT CONSIDERATIONS REGARDING THE OUTPUT CIRCUIT: PRECAUTIONS NECESSARY TO AVOID EXCESSIVE PEAK VOLTAGES.—L. G. A. Sims. (*Wireless World*, 16th January, 1929, V. 24, pp. 60–64.)

One interesting point is that serious damage to the valve may result from the high voltages produced by injudicious manipulation, *e.g.*, if the loud speaker is disconnected from the pentode while the filament of the latter is alight.

LA TRIGRILLE À FONCTIONS MULTIPLES (The Five-Electrode Valve for Multiple Functions).—R. Barthélemy. (*T.S.F. Moderne*, July, 1928, V. 9, pp. 396–400.)

Description of a circuit (" trisodyne ") in which the 3-grid valve gives H.F. amplification and a frequency change: with reaction in the primary circuit and also in the beat-note circuit. A set using this circuit, with 4 three-electrode valves (one for medium frequency, one for detection and two for L.F.) gives results " comparable, if not superior " to those obtained with 7 or 8 valves with the usual frequency-changing circuits.

RECHERCHE DE LA QUALITÉ ACOUSTIQUE DANS LES RÉCEPTEURS SÉLECTIFS (Search for good quality in selective Receivers).—P. Borias. (*Bull. d.l. Soc. Fr. Rad.*, November, 1928, pp. 3–12.)

The particular object is to receive a distant station without interference from a nearer station and without loss of quality. A series of coupled L.F. circuits is recommended, a resultant tuning curve with a flat plateau from 0–4,000 being obtained by suitable shifts of the tuning of each circuit away from the mid-point.

SUR LE CALCUL DES AMPLIFICATEURS À MOYENNE FRÉQUENCE POUR SUPERHÉTÉRODYNE (The Calculation of Medium Frequency Amplifiers for Superheterodyne Reception).— —. Boella. (*L'Onde Élec.*, November, 1928, pp. 500–508.)

Author's summary: It is shown how one can determine, in a stage with transformer with tuned secondary, the primary inductance to give maximum amplification, provided the constants of the secondary are known. From this are deduced the elements of a medium frequency amplifier for a superheterodyne, to receive telephony under good conditions of selectivity and fidelity. The example taken has 3 stages, plus detector, for a carrier wave of 200 kc./s., to give practically constant amplification for modulation frequencies 100–4,000 p.p.s.

BROADCAST RECEIVERS: LOEWE TYPE O.E. 333 WITH MULTI-ELECTRODE VALVE: A LOW-PRICED LOCAL STATION RECEIVER OF NOVEL DESIGN AND CONSTRUCTION.—(*Wireless World*, 16th January, 1929, V. 24, pp. 79–81.)

THE NEW EMPIRE RECEIVER: A STABLE SET COVERING ALL THE SHORT WAVELENGTHS.—H. F. Smith. (*Wireless World*, 26th December, 1928, V. 23, pp. 854–859.)

SCREEN GRID VOLTS: HINTS ON REGULATING AND MEASURING VOLTAGE.—" Radiophare." (*Wireless World*, 16th January, 1929, V. 24, pp. 70–71.)

AERIALS AND AERIAL SYSTEMS.

RADIO TRANSMITTING AERIALS.—P. P. Eckersley, T. L. Eckersley, and H. L. Kirke. (*Elec. Review*, 11th January, 1929, V. 104, pp. 84–85.)

Extracts from the I.E.E. paper on the Technical Aspect of the Design of Broadcast Radio-Telephone Radiating Aerials.

HIGH ANGLE RADIATION: THE EXPERIMENTAL 28,000 KC. (10-METRE) BEAM ANTENNA AT 1 CCZ.—P. S. Hendricks. (*QST.*, October, 1928, V. 12, pp. 31–32.)

Diagram and photographs of a rotatable aerial system (fundamental antenna, fed in the " Zeppelin " fashion, operating in conjunction with three reflector wires and two director wires arranged according to Uda and Yagi) set up with the idea of testing from America to Australia. An account of some tests is given in the January, 1929, issue (pp. 13–16) by R. A. Hull, in his article " The Status of 28,000-kc. Communication." Transmission from Cape Cod was received much the best, both in California and in New Zealand, when the beam was directed at an angle of 30 deg. to the horizontal; fading, which was severe at some angles, disappeared almost completely at this angle.

WHAT LENGTH ANTENNA ?—J. J. Lamb. (*QST*, October, 1928, V. 12, pp. 49 and 76.)

Experiments on di-pole aerials having fundamental wavelengths of from 10–80 m., vertical or horizontal, high above ground or within a quarter wavelength, operated on fundamental or on harmonics, led to a universal value of 2.1 for the ratio fundamental wavelength/antenna length; agreeing with Englund's results for horizontal di-poles (5.36–6.34 m.) and Wilmotte's 4.2 for grounded aerials (15–800 m.).

THE ZEPP: FACTS AND FIGURES FOR THE DESIGN OF THE HERTZ ANTENNA WITH TWO-WIRE VOLTAGE FIELD.—J. J. Lamb. (*QST*, September, 1928, V. 12, pp. 33–36, 86 and 88.)

INFLUENCE OF ATMOSPHERIC POLLUTION ON PERFORMANCE OF LINE INSULATORS.—B. L. Goodlet and J. B. Mitford. (*Electrician*, 25th January, 1929, V. 102, pp. 91–95.)

A special investigation of troubles experienced in Britain—Performance of Fouled Insulators—Action of Coal Smoke—The Wind Factor—Points in Insulator Design.

SUSPENSION INSULATORS FOR H.T. TRANSMISSION LINES.—C. S. Garland. (*Electrician*, 25th January, 1929, V. 102, pp. 109–110.)

Overcoming difficulties due to expansion of cement—The "Spring Ring" Insulator—Increasing tensile strength—Employment of Steatite—New insulators for special purposes.

DEVELOPMENT OF GLASS INSULATORS FOR TRANSMISSION SCHEMES.—N. E. North. (*Electrician*, 25th January, 1929, V. 102, pp. 101–102.)

Some Advantages of Glass for Electrical Purposes—Examination under Polarised Light—Possible New Uses—The Proper Sealing Method.

AERIALS AND GALES.—(*Electrician*, 30th November, 1928, V. 101, p. 624.)

A paragraph mentioning the successful weathering of the November gales by the Marconi Beam aerial systems. The normally tightly strained wires are provided with safety devices which reduce the tension at the lower ends when a hurricane is tending to cause excessive strain.

ZUR MECHANISCHEN SICHERHEIT VON FREILEITUNGSEILEN (The Mechanical Safety of Open Line Cables).—A. Fuchs and H. Wiesthaler. (*E.T.Z.*, 22nd November, 1928, pp. 1705–1713.)

The writers show that the present V.D.E. regulations concerning the requirements of conducting materials for overhead lines no longer comply with present-day knowledge. New regulations are suggested which will embody the latest results of research (many curves representing which are given) and include the recently developed metals such as Aldrey, which in many cases is a good substitute for copper.

GRAPHICAL DETERMINATION OF STRESS AND SAG OF OVERHEAD LINES.—A. Thiry. (*Elektrot. u. Masch: bau.*, 6th May, 1928, V. 46, pp. 421–426.)

The problem is to determine the stress and sag of a given line at a given temperature when the values are known for another temperature.

WIND PRESSURES ON WIRES.—W. B. Woodhouse. (*Nature*, 1st December, 1928, V. 122, p. 859.)

Summary of a paper read before the I.E.E. on November 8th on the results of tests made at the National Physical Laboratory for the British Electrical Research Association. The theoretical relation, that the ratio of the pressure on a smooth cylinder to the product of the wind speed and the projected area should be a constant (provided that the product of the wind speed and the diameter of the wire remain the same), has been verified experimentally. The law does not apply to stranded cables. Tests on wooden poles show that the usual design could be greatly improved by modification. The wind pressure on a strut of circular cross section can be considerably reduced by the addition of a similar strut in its wake. Wind pressures on two struts of equal mechanical strength may be in the ratio of 6 to 1, depending on the shape of their sections. At certain speeds the pressure on a sphere can be reduced by roughening its surface.

VALVES AND THERMIONICS.

INTERACTION OF ELECTRON AND ION SPACE CHARGES IN CATHODE SHEATHS.—I. Langmuir. (*Abstract in Phys. Review*, 1928, V. 31, p. 1121.)

The usual space charge problem for electrons from a plane hot cathode to a parallel plane anode is modified by assuming positive ions emitted from the anode. Single ions emitted with negligible velocity allow 0.378 $(m_p/m)^{\frac{1}{2}}$ additional electrons to pass. An unlimited supply of ions gives an electron current 86.05 per cent. greater than with no ions, the field is symmetrically distributed between cathode and anode, and the electron current is $(m_p/m)^{\frac{1}{2}}$ times the ion current. These conditions apply to a cathode emitting a surplus of electrons surrounded by uniformly ionised gas. The cathode sheath is a double layer with an inner negative space charge and an equal outer positive charge, the field being zero at the cathode and at the sheath edge. The electron current is limited to $(m_p/m)^{\frac{1}{2}}$ times the rate at which ions diffuse to the sheath edge and is independent of voltage if the source of ions is constant. Experiments with oxide cathodes in mercury vapour agree with this theory, which has been extended to take into account initial velocities of ions and ultimate electrons, and also to deal with cylindrical sheaths.

IONIC OSCILLATIONS IN THE GLOW DISCHARGE.—L. A. Pardue and J. S. Webb. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 946–949.)

The first stage of an attempt to correlate Whiddington's work on moving striæ and Appleton's work on ionic oscillations from a striated discharge. In a hot cathode discharge tube, 26 cm. long, ionic oscillations from 15×10^4 to a few hundred cycles were obtained. Characteristic curves show an increase of frequency with filament current or with anode potential, and a decrease with pressure except at the lower pressures, where the frequency increases and passes through a maximum. With a varying pressure and without plates on the tube, oscillations do not occur when there are sharply defined striæ, but begin just as striæ begin to diffuse, decreasing in frequency and becoming audible when a uniform glow fills the tube.

EINFLUSS POSITIVER IONEN AUF DIE ELEKTRONEN-RAUMLADUNG INNERHALB EINES ZWEIPLATTEN-SYSTEMS (The Influence of Positive Ions on the Electronic Space Charge in a Two-plate System).—H. Cohn. (*Ann. der Physik*, No. 20, V. 87, pp. 543–569.)

In a brief reference to this article (Abstracts, 1929, V. 5, p. 44) the number of the journal was wrongly given as No. 4. Some results of the measurements are: the gas ions produced by the electrons tend to neutralise the space charge, by an amount directly proportional to the pressure

of the gas and the mass of the gas atom, and inversely proportional to the absorption of the electrons by the gas molecules. For very small pressures, the voltage necessary for the neutralising effect is greater than the ionisation-voltage. It is dependent on the number of electrons flowing through the valve before neutralisation. The neutralisation effect is independent of the value of the saturation current of the cathode. In a particular arrangement used it was calculated that a positive ion-stream of 2 mA. would be necessary to neutralise completely the space charge. This could not be supplied by the filament: another source would be necessary.

MOTION OF ELECTRONS IN A VALVE GENERATING SHORT ELECTRIC WAVES OF THE BARKHAUSEN-KURZ TYPE.—N. Kapzov. (*Zeitschr. f. Phys.*, 1928, V. 49, No. 5/6.)

The motion of electrons in a variable field, due to potential variations of the grid and anode of a valve, is discussed theoretically and the conclusions applied to the process leading to the B-K oscillations.

THE THERMIONIC EMISSION CONSTANT A.—R. H. Fowler. (*Proc. Roy. Soc.*, 1st January, 1929, V. 122A, pp. 36–49.)

"The main object of this paper is to apply Nordheim's theory of the emission coefficient of electrons from metals so as to explain the remarkable relation between the constants A and χ of the thermionic emission formula, first recorded by O. W. Richardson and recently reformulated by DuBridge ($\log A = \xi + \eta\chi$, where $\eta > 0$, ξ and η being constants, η in particular depending on the type of surface dealt with). . . . Assuming the absolute values of A can be accounted for, the rest of the existing theory of thermionic emission is extremely satisfactory on account of the beautiful explanation which it gives of the general form of this relation."

THE THERMIONIC EMISSION FROM CLEAN PLATINUM.—L. DuBridge. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 961–966.)

The data confirm the previous announcement that A is 250 times greater than the theoretical value of 60.2 amp/cm.^{2} deg.^{2}. *Cf.* Abstracts, 1929, V. 6, p. 44.

ÜBER EIN VERFAHREN ZUR AUSLÖSUNG VON ELEKTRONEN UND DESSEN ANWENDUNG (A Method for Setting Free Electrons, and its Applications) *and* EXPERIMENTELLES ÜBER DEN ELEKTRON-AUSTRITT AUS METALLEN (Experimental Work on the Electron Emission from Metals).—F. Rother. (*Summaries in E.T.Z.*, 13th December, 1928, p. 1817.)

The first paper deals with experiments on the emission from cold electrodes in high fields, to check the results of Millikan and Eyring, which disagreed with the curves calculated by Schottky's theory. As causes for the discrepancies are suggested traces of gas in the anode cylinder and the destruction of the atomic thorium-layer on the wire, under the influence of the steep field gradient. The second summary gives details of experiments on cold wires, measurements being taken with all possible precautions. The cathode in one case was a wire of an alloy of thorium and molybdenum, 70 mm. long and 0.15 mm. in diameter, with a tantalum anode 40 mm. long and 20 mm. in diameter. Up to 6,000 v. no current greater than 10^{-11} A was found. At higher voltages the current increased quickly, its upper limit was given by the melting of the anode. With a pulsating D.C. field of the same mean value the emission was notably larger: at 6,000 v. the anode became bright red at once, the current being 3 mA.

THE EFFECT OF THE IMAGE FORCE ON THE EMISSION AND REFLECTION OF ELECTRONS BY METALS.—L. W. Nordheim. (*Proc. Roy. Soc.*, 3rd December, 1928, V. 121A, pp. 626–639.)

LES CAPACITÉS INTERNES DE LA LAMPE À PLUSIEURS ÉLECTRODES (Internal Capacities of the Multi-electrode Valve).—C. Rajski. (*L'Onde Élec.*, November, 1928, pp. 461–474.)

Author's summary: The author shows that the electro-static formula cannot be used for the calculation of the internal capacities of electronic valves. The correct calculation necessitates the study of the field around the valve electrodes; he carries out this calculation for the cases of flat and cylindrical electrodes. He deduces from it that in a triode, instead of the three capacities filament-grid, filament-plate, and grid-plate (which are the only ones to be considered in a valve out of action), four capacities must be reckoned with: self-capacity of grid $\left[\frac{\partial Q_g}{\partial V_g}\right]$, self-capacity of plate $\left[\frac{\partial Q_a}{\partial V_a}\right]$, grid-plate capacity $\left[\frac{\partial Q_a}{\partial V_g}\right]$, and plate-grid capacity $\left[\frac{\partial Q_g}{\partial V_a}\right]$.

In the course of the article, equations for all these quantities are obtained. The last capacity (C_{ag}) is a component of the input capacity (capacité d'entrée) thus:

$$C_{\text{input}} = C_g - C_{ag} \cdot \frac{K}{1 + \rho R},$$

and itself forms a coupling capacity between plate and grid—a direct cause of difficulties in H.F. amplifiers, and the provider of coupling in the Kühn-Huth oscillator. Its expression, given for plane electrodes as

$$C_{ag} = \frac{S}{4\pi(K + 1)} \cdot \left(\frac{4}{3x_g} - \frac{K}{x_a - x_g}\right)$$

(though elsewhere—p. 469—a different expression is used which does not appear to be equivalent) indicates that theoretically it could be rendered zero by suitably dimensioning the valve. This could only be done in practice, however, for plane electrodes and small amplification constants. The author discusses the interpretation of the difference, in a functioning valve, between the capacities plate-grid and grid-plate.

PRODUCTION OF OXIDE-COATED CATHODES.—(*German Patent No.* 465,278, Philips Lamp Co., pub. 14th September, 1928.)

DIE NEUE PHILIPS-HOCHFREQUENZRÖHRE. A-442 MIT SCHIRMGITTER (The new Philips H.F. Valve A.442 with Screen Grid).—A. van Sluiters and C. J. van Loon. (*Suppt. to Elektrot. u. Masch : ba::.* No. 10, 14th October, 1928, pp. 89–92.)

Designed chiefly for H.F. amplification with tuned-anode circuit, this valve has a grid-plate capacity of only 0.01 cm.

DIE TELEFUNKEN-RUNDFUNK-RÖHREN 1928 (Telefunken Broadcast Receiver Valves, 1928).—G. Jobst. (*Telefunken Zeit.*, October, 1928, No. 50, pp. 29–34.)

DIRECTIONAL WIRELESS.

THE REVERSIBILITY OF RADIO DIRECTION-FINDING AND LOCAL ERROR AT ROTATING-LOOP BEACONS.—R. L. Smith-Rose. (*Journ. I.E.E.*, January, 1929, V. 67, pp. 149–156.)

Author's summary : In this paper consideration is given to the applicability of the reciprocal theorem to the practice of radio direction-finding with either a rotating loop transmitter or a loop receiver. A description is given of some experiments carried out with the object of demonstrating that the permanent errors to which a rotating-loop beacon transmitter may be subject as a result of conditions local to its site are similar to those observed on a direction-finder erected on the same site. This similarity has materially assisted in locating the cause of the permanent error associated with the rotating beacon erected at Fort Monckton, near Gosport. From other experiments carried out under suitable conditions, it is shown that the occurrence of night errors is experienced on both systems of direction-finding to approximately the same extent. *Cf.* Abstracts, 1928, V. 5, pp. 36, 288 and 402.

WATER RIPPLES AND WIRELESS WAVES.—A. H. Davis. (*Wireless World*, 16th January, 1929, V. 24, pp. 56–59.)

"An interesting analogy explaining certain direction-finding phenomena." Photographs of ripples under various conditions illustrate not only the deflection of waves at a partially reflecting boundary (analogous to the Heaviside layer) but also effects analogous to the phenomena of coastal refraction and reflection also observed in direction finding.

ACOUSTICS AND AUDIO-FREQUENCIES.

EFFECT OF DIFFRACTION AROUND THE MICROPHONE IN SOUND MEASUREMENTS.—S. Ballantine. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 988–992.)

Proposed method of evaluating the pressure correction made necessary by diffraction : Theory of the diffraction of a sound wave by a rigid sphere (this second section is called for by the use of a spherical mounting proposed in the first section).

A PHOTOGRAPHIC METHOD OF MEASURING PITCH.—M. Metfessel. (*Science*, 2nd November, 1928, V. 68, pp. 430–432.)

The usual photographic methods (Phonodeik, phonelescope, Lapp Undulator, etc.) use a costly amount of film and require much time. The stroboscopic methods are often useful but do not give a continuous record. The present method is in a sense a combination of these two : the vibrating light passing through the equally spaced apertures of the numerous circular rows on the stroboscopic disc or drum, being photographed on film (stationary or moving) on the other side. If the film is stationary, the light passing through the particular row of holes which corresponds to the pitch will produce dots : through other rows it will form dashes.

ON THE VARIATION OF SOUND WITH DISTANCE.—L. A. Sokolov. (*Journ. Applied Phys.*, Moscow, No. 3/4, 1928, V. 5, pp. 235–245.)

Owing to the different sensitivities of the ear to sounds of different pitch, the tone-colour of a sound depends on the distance. If the fundamental is low, perception of the higher overtones improves if the distance is increased ; if it is high, it drowns the overtones at a distance.

A THEORETICAL STUDY OF THE ARTICULATION AND INTELLIGIBILITY OF A TELEPHONE CIRCUIT.—J. Collard. (Discussed in *Nature*, 5th January, 1929, V. 123, p. 24.)

From the subscriber's point of view, the efficiency of a telephone circuit should be judged by the relative time required to convey correctly a given number of ideas. Tests show that this is shortest for French, and then come English, German and Italian. The order for "intelligibility" (ratio of number of ideas correctly received to total number transmitted) is Italian, German, English and French. "It is quicker to speak a language of short words, even when some of the sentences have to be repeated owing to the low intelligibility, than to speak a language of long words which has a relatively high intelligibility." No consideration, however, is here apparently given to errors which are not perceived and therefore not corrected by repetition.

ZUR THEORIE DES HÖRENS : DIE SCHWINGUNGSFORM DER BASILARMEMBRAN (On the Theory of Hearing : The Nature of the Vibrations of the Basilar Membrane).—G. v. Békésy. (*Physik. Zeitschr.*, 15th November, 1928, pp. 793–810.)

THE IMPEDANCE OF A MOVING-COIL LOUD SPEAKER.—N. W. McLachlan. (*Wireless World*, 28th November, 1928, V. 23, pp. 729–732.)

"How the relative constants of the output stage and the moving coil affect the general character of reproduction." A previous paper (*Wireless World*, 1927, p. 372) is referred to and its results are extended so as to be free from the conditions under which they were obtained. Thus in the previous paper the coil was a high resistance one, so that any complication due to a transformer was avoided :

the diaphragm was free from resonances, whereas in practice it often has marked resonances: the inductance and resistance of the coil was assumed to be constant at all frequencies, whereas there is a variation. Among the various points developed, the importance is shown of designing so that the surround resonance-point is well below the working frequency range; in a quoted case, the influence of the surround resonance about doubled the loud-speaker impedance. If the higher frequencies are too strong, of the various remedies the one of increasing the turns on the moving coil has the advantage of augmenting the acoustic output.

ÜBER NEUERE AKUSTISCHE . . . (New Work on Acoustics . . .).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, December, 1928, V. 32, pp. 202–206.)

Conclusion of the survey referred to in previous Abstracts. Curves are given showing the dependence of the amplitude-frequency curve of a condenser-microphone on the pressure of the air forming the air-cushion behind the membrane. Curves are also given for Riegger, ordinary telephone and the Gerlach band microphones. The ground-noise listener (Waetzmann), used for detecting mining operations in war, is illustrated. The rest of the paper deals with speech and hearing.

A NEW LOUD SPEAKER: THE USE OF GLOW-DISCHARGES TO CREATE SOUND-WAVES FROM VOLTAGE CHANGES. (*Wireless World*, 16th January, 1929, V. 24, p. 64.)

An article on the Brenzinger-Dessauer loud speaker referred to in Abstracts, 1928, V. 5, p. 645.

A.C. GRAMOPHONE AMPLIFIER.—N. P. Vincer-Minter. (*Wireless World*, 5th December, 1928, V. 23, pp. 755–760.)

THEORY OF VIBRATING SYSTEMS AND SOUND.—I. B. Crandall. (*Proc. Inst. Rad. Eng.*, November, 1928, V. 16, p. 1574.)

A short review, by A. Hund, of this book based on studies in the Bell Telephone Laboratories.

DISPERSION AND ABSORPTION OF HIGH FREQUENCY SOUND WAVES.—K. F. Herzfeld and F. O. Rice. (*Phys. Review*, April, 1928, V. 31, pp. 691–695.)

In addition to internal friction and heat conduction, the absorption and dispersion of sound waves is greatly influenced by the interchange of translational and intramolecular energy. Equations here developed (and applied to data on the velocity of high frequency sound waves) show that this energy exchange can be of great—in many cases preponderant—effect.

PHOTOTELEGRAPHY AND TELEVISION.

TELEVISION ABROAD.—A. G. Ingalls. (*Scient. American*, December, 1928, pp. 550–552.)

An article by an Associate Editor of the Journal, who is travelling in Europe. He deals only with his impressions of the Baird system; he was unable to see either the stereoscopic television or (it seems) the colour television, both of which he outlines; but he seems to have gained a fairly favourable impression of ordinary monochrome television. His final answer, after some hesitations, to the question whether it is "better" than some of the American systems is that "in general, the respective results seemed not so much better or poorer as quite different." He mentions elsewhere the more black-and-white effect produced by the Baird system as compared with the orange-red tone of the ordinary neon tube.

RUNDFUNK UND BILD (Broadcasting and Pictures).—F. Schröter. (*Telefunken Zeit.*, October, 1928, No. 50, pp. 7–16.)

A description of recent Telefunken progress in connection with picture telegraphy, synchronised cinematography (a half-way house between still-picture telegraphy and television or telecinematography) and these last two problems. The writer concludes that these, in spite of the latest brilliant results of Karolus (whose new apparatus is described and illustrated), still require development at the hands of inventors; whereas synchronised cinematography simply needs cheapening, mass production of narrow paper or cellophane films, etc. Karolus' latest apparatus for telecinematography uses 10,000 elements in place of the usual (Bell Laboratory and elsewhere) 2,500, special analysing discs being employed which "by the alternating action of *n* hole-spirals" produce *n* times the surface for a given number of elements or *n* times the elements for a given size of picture. On p. 54 is given a photograph of his large mirror-wheel used at the receiving end.

RADIOVISION. (*Science*, 16th November, 1928, V. 68, Supplement, p. xii.)

"The amateur radiovision enthusiast will soon have at least 21 stations broadcasting such programmes, located all the way from Lexington to Los Angeles. These are operated by eleven different broadcasters. Nine are now broadcasting, while two have their stations under construction." Radio Corporation has three bands allotted, of 100 kc. width; it is already using one. G.E.C. is regularly broadcasting on three different frequencies (10 kc. width) including 790 kc. (WGY). The Westinghouse Co. has been assigned two bands of 100 kc. width, at 63 and 150 m. Federal regulations and restrictions are mentioned; they appear generous at present, but there are to be further re-allocations of the radiovision bands. The "standard" 48-line, 15 picture p.s. has been adopted by four of the broadcasters only at present. Others are using fewer lines, or fewer pictures p.s., in an effort to get more varieties of light and shade in the limited (10 kc.) bands assigned. "With the 100 kc. band that will be used in the future" (in the re-allocation) "it will be possible to send considerable detail" with the standard arrangement.

Another paragraph (*ibid.*, 9th November) quotes Gray and Ives on the subject of outdoor television. The problem of full-length figures or groups of figures (the satisfactory television of which was prophesied to need a very much finer grained

image) has been found to be greatly simplified by a psychological effect—it appears that when full length figures are observed, one's expectation of rendering of detail is automatically reduced. "With our 50-line (2,500-element) images, which are just sufficient for the transmission of clearly recognisable faces, the rendering of full length figures or even of two or three figures simultaneously is surprisingly satisfactory."

OPTICAL CONDITIONS FOR DIRECT SCANNING IN TELEVISION.—F. Gray and H. E. Ives. (*Journ. Opt. Soc. Am.*, December, 1928, V. 17, pp. 428–434.)

Direct scanning, by sunlight or flood-lighting on the object, originally gave too small photoelectric currents and was abandoned in favour of beam-scanning (Abstracts, 1928, V. 5, p. 410). Lately, however, good results with direct scanning have been obtained by increasing the dimensions of the scanning disc so that the disc holes are several times larger than usual, and by increasing the aperture of the lens to nearly its present limit of F/2. Greatly increased sensitiveness of a new type of cell (a description of which is promised later) has rendered it unnecessary to go to the largest practicable disc size (say 10 ft. diameter), and good results—with sunlight—have been obtained with a 3ft. disc and a lens aperture of F/2.5. The writers deal with the consideration of the defining power of the lens in relation to its size and to the size of the field it covers; also with the question of increasing the number of image elements, showing how, considering all things, doubling the number of image elements would demand a disc between 2 and 3 times the original diameter. They then describe the apparently psychological effect recently found, as to the good results of full length figure reproduction with only 2,500-element images (see above Abstract).

RADIOVISION.—T. P. Dewhirst. (*QST.*, September, 1928, V. 12, pp. 15–18.)

An American radio consultant's views on what may be expected at present and in the future. In its present state "it is merely a plaything for the amateur and experimenter." The use of present-day channels limits the number of lines drawn per picture to about 24; this means that the bust of a single person is about the limit of recognisable reproduction in half-tone work, or possibly two moving figures in silhouette. A 48-line picture sent 15 times per sec. will require about 20 kc's. for each side band—or about 4 present-day channels. For this work, receivers must differ considerably from those employed now for broadcast reception. One "stunt" is to use four channels, splitting the picture into 4 parts, each of which is handled by a separate transmitter and receiver. Various details of apparatus and methods are discussed, including special forms of disc.

TELEVISION.—C. R. Cosens. (*Wireless World*, 16th January, 1929, V. 24, pp. 81–82.)

A letter, the gist of which is that before television can become more than a scientific toy a very great speeding-up and increase in the number of elements of pictures that can be transmitted per second will be necessary; at present, to produce a picture one foot square with definition equal to that of the illustrations in *The Wireless World* would require a sideband of over 5,000 kilocycles—"the transmitter would require as much space in the ether as several hundred broadcasting stations." *Cf.* Korn, February Abstracts.

BILDÜBERTRAGUNG UND FERNSEHEN (Picture Telegraphy and Television).—R. Hiecke. (*Supplement to Elektrot. u. Masch. bau*, No. 10, 14th October, 1928, pp. 92–94.)

A continuation of the historical survey referred to in Abstracts, 1928, V. 5, p. 649. The present paper starts with 1921 and later deals at some length with Dauvillier's work from 1908 to 1925, particularly the later work on the "Telephot" in which, inspired by Campbell Swinton's researches, he used a cathode ray oscillograph at the receiving end. Zworykin's system (1925) of colour television is also mentioned, using the cathode ray with tri-coloured mosaic filters in front of the fluorescent screen.

The next instalment (No. 12, 9th December, 1928, pp. 107–112) is devoted to the great advance in America during 1927, indicated by the Bell Telephone Company's Washington–New York television demonstration. The apparatus is treated in considerable detail. The next step to be expected from these laboratories is the dividing up of the picture into several portions transmitted simultaneously.

AN HOUR WITH A PICTURE RECEIVER.—"Empiricist." (*Wireless World*, 5th December, 1928, V. 23, pp. 752–754.)

The writer has just secured one of the first batch of Fultograph machines, and describes and illustrates his first results on the transmissions from Königswusterhausen (and also from Paris; distortion was produced owing to Paris not transmitting on the Fultograph system). The set works well on signals too weak for loud-speaker reproduction; it requires only 3 mA. mean current. A good volume control is desirable, and the receiver must be selective. The chief trouble with the German signals was interference from 5XX, causing streaks.

BUILDING A PICTURE RECEIVER.—F. H. Haynes. (*Wireless World*, 2nd January, 1929, V. 24, pp. 2–6.)

UN NOUVEAU SYSTÈME DE TÉLÉVISION ET DE TÉLÉCINÉMATOGRAPHIE (A New System of Television and Telecinematography).—L. Thurm. (*QST Franç.*, November, 1928, pp. 40–42.)

A continuation of the article referred to in Abstracts, 1928, V. 5, p. 529. The author first describes the advantages of his plan (of slowing down the rate of actual wireless transmission and reception, so that this takes several times the length of time of the action itself) and then shows how it can be applied in practice to telecinematography—taking this as more simple for purposes of explanation than television itself. The camera

would preferably use a film in uniform motion (instead of intermittent) with an opaque shield passing across its breadth, perforated with narrow rectangular slots at intervals equal to the breadth of the film, the length of these slots being in the direction of the length of the film and equal to its breadth. Thus the images take the form of a series of parallelograms slanting across the film, one below the other. The film thus made is used with a special scanning disc, and a photoelectric cell, to modulate the wireless transmitter. If only one wave channel is used, the whole film is passed through perhaps forty times, only two narrow longitudinal strips being scanned in each passage. The next instalment will deal with the reception and the frequency change necessary to reproduce the action at the proper speed.

FACSIMILE TELEGRAPHY.—(German Patent No. 464568, Siemens & Halske, pub. 21st August, 1928.)

To reduce the time of transmission, the white spaces are cut down as much as possible by having the writing on a tape or tapes wound on the picture drum. In the diagram, one tape is wound three times spirally round the drum, so that it looks not unlike the arrangement for "slanting line-jump scanning" (Schröter, February Abstracts).

SYNCHRONISM.—C. F. Jenkins. (*QST.*, September, 1928, V. 12, p. 38.)

It is here advocated that the motor should be run at the speed for which it is designed, as this will result in greater constancy. Regulation should be done by adjusting the position at which the rubber friction drive touches the disc.

SYNCHRONISATION.—(German Patent No. 464491, Karolus, published 21st August, 1928.)

To avoid the great amplification needed for the usual synchronisation by tuning forks, the apparatus is driven roughly in time by an asynchronous motor and the finishing touches are supplied by a small synchronous motor on the same axis, controlled by the tuning fork. In the diagram the synchronous motor takes the form of a round-toothed wheel (made up of iron laminæ) whose teeth pass close to the poles of an electromagnet.

NOUVEAU DISPOSITIF POUR L'ENREGISTREMENT SIMULTANÉ DE TROIS IMAGES SÉLECTIONNÉES POUR LA PRODUCTION D'IMAGES EN COULEURS (New Arrangement for the Simultaneous Blending of Three Selected Images for the Production of Images in Colour).—C. Nachet. (*Comptes Rendus*, 10th December, 1928, V. 187, pp. 1172–1174.)

CONTROL OF A KERR CELL.—(German Patent No. 464626, Telefunken, pub. 23rd August, 1928.)

The secondary winding of the transformer linking the Kerr cell to the amplifier should be very high to match the cell resistance, but a limit is put on it by the self-capacity of the primary and secondary windings. This capacity is here kept low by reducing the primary winding, by the use of a microphone in the primary circuit instead of a valve.

PHOTOELECTRIC RELAY.—(French Patent No. 644820, Siemens and Halske, published 15th October, 1928.)

The double refraction of glass or similar substance under the action of deformation stresses is here used without any employment of piezoelectric vibration, the deformation being produced by the electromagnetic attraction of an armature secured to one end of the glass, the other end being rigidly fixed.

LIQUID-FILLED PHOTO CELL.—(*Scient. American*, December, 1928, p. 552.)

Paragraph noting the production, by the Radiovision Corporation of New York City, of a photovoltaic cell resembling a "large radio vacuum tube filled with a greenish liquid." It is said to generate 1,000 times the current generated by the present-day photoelectric cell.

MARKING DEVICE FOR PICTURE TELEGRAPHY.—(German Patent No. 464954, Radio Corp., published 4th September, 1928.)

To avoid clogging of the ink at the pen-point when this is off the paper, the pen is kept all the time rubbing against the paper but is fed with ink at varying pressure.

PICTURE TELEGRAPHY.—(German Patent No. 464490, Hausmann, published 21st August, 1928.)

For every line of the picture a separate frequency is to be used, these frequencies being generated by a rotating siren disc. At the receiver a corresponding collection of resonators is to be used, consisting of a number of piezo crystals.

PREPARATION OF THE THALLIUM PHOTOELECTRIC CELL.—Q. Majorana and G. Todesco. (*Roy. Nat. Ac. Lincei*, abstracted in *Nature*, 5th January, 1929, V. 123, p. 34.)

A quick-acting cell, at least as sensitive as that of Case, may be prepared from thallium sulphide. *Cf.* next abstract, Dubois.

ÉTUDE DES PROPRIÉTÉS DES CELLULES PHOTOÉLECTRIQUES FOURNIER (The Properties of the Fournier Photoelectric Cells).—R. Dubois. (*Journ. d. Phys. et le Radium*, October, 1928, V. 9, pp. 310–336.)

These cells have a very thin crystalline deposit of metallic sulphide, the resistance of which decreases with illumination. Their properties differ from those of a selenium cell; they will follow light variations of very high (ultrasonic) frequencies, and their sensitivity extends into the visible and the nearer infra-red region ($\lambda = 0.5 - 1.3\mu$). On p. 322 the sensitivity of such a cell on 6 volts (not the maximum 45 v.) is given as 2,000 times as great as that of a potassium cell with 150 v. accelerating potential. Moreover, as the response of the Fournier cell varies with the square root of the illumination, instead of with the first power, it gains still more at

weak illuminations. Full details of the behaviour of these cells, and a theory explaining it, are here given.

ATOMIC LAYERS OF RUBIDIUM.—Bell Telephone Laboratories. (*Science*, 2nd November, 1928, V. 68, Supplement, p. xii.)

A paragraph on Johnsrud's researches in connection with photoelectric cells. The rubidium was gradually deposited or (alternatively) a thick deposit was gradually thinned, and the photoelectric response measured during the process. Maximum response was obtained when the film was only one atom thick, as determined by polarised light.

PHOTO-ELECTRIC THRESHOLDS AND FATIGUE.—G. B. Welch. (*Phys. Review*, October, 1928, V. 32, No. 4, pp. 657–666.)

A linear relation was found between the logarithms of the photoelectric current and the logarithm of the time elapsed since polishing the surface. The rate of fatigue depends upon the element used, and—for a given substance—increases numerically as the threshold is approached. Increasing the gas pressure increases the rate of fatigue. The action of light has a negligible effect. The threshold wavelengths for various elements are given ; with a high vacuum, fatigue produces no change in these at any rate over several hours. With lower vacua there is evidence of a shift towards shorter wavelengths. A "patch" theory, in which it is supposed that contamination takes place at discrete areas of the surface, is suggested to account for the experimental facts obtained.

ÜBER DIE SÄTTIGUNG DES LICHTELEKTRISCHEN STROMES (The Saturation of Photoelectric Current).—J. A. Becker. (*Naturwiss.*, 4th January, 1929, p. 12.)

Suhrmann has found that light of high frequency produces a current which gives a saturation effect, whereas light in the neighbourhood of the long wave border produces a current increasing regularly with an increase of potential. The writer explains this on thermionic and quantum principles.

WAVE MECHANICS OF AN ALKALINE ATOM IN THE ELECTRIC FIELD.—F. Rasetti. (*Nature*, 29th December, 1928, V. 122, p. 1018.)

Short abstract of a paper read before the Royal Nat. Acad. Lincei, 17th June, 1928. The theory (previously developed by the same worker) of the perturbation due to the effect of an external field on an atom of an alkali metal is applied to the case of lithium.

MEASUREMENTS AND STANDARDS.

DIE TEMPERATURABHÄNGIGKEIT DER FREQUENZ DES QUARTZRESONATORS (The Variation with Temperature of the Frequency of Quartz Oscillators).—F. Gerth and H. Rochow. (*E.N.T.*, December, 1928, V. 5, pp. 549–551.)

Previous results have differed quite seriously : in the tests here described, silvered quartz plates were used ; thus the uncertain distance of the electrodes from the quartz—a frequent source of error—was avoided. The resulting value (60×10^{-6} per degree Centigrade) of temperature coefficient is considerably higher than those given by most workers, and leads to the conclusion that (for example) for a wavelength of 15 m. the temperature of the crystal must be kept constant to within 1/25th degree Centigrade in order to keep the frequency constant within 50 cycles per second. It is mentioned that Mason has given the temperature coefficient of a particular tuning fork as -4.7×10^{-6}, less than a tenth of the value here found for quartz.

NOUVEAU MODE DE DÉVELOPPEMENT D'ÉLECTRICITÉ PAR TORSION DANS LES CRISTEAUX DE QUARTZ (New Method of Developing Electricity by Torsion in Quartz Crystals).—E. P. Tawil. (*Comptes Rendus*, 3rd December, 1928, V. 187, pp. 1042–1044.)

A cylinder of quartz cut with its axis parallel to the optical axis, when fixed at one end and subjected to torsion at the other, displays a disengagement of electricity on its surface which appears to be proportional to the variation of the effort of torsion ; the polarity of the charge reverses when the direction of torsion reverses or if the torsion is removed. The respective polarities depend on the optical structure : positive electricity is developed whenever the torsion is in the direction of the optical rotation. A natural prism will show the effect : if long enough and not too big, sufficient twist can be applied by the two hands, without any mounting. Incidentally, the direction of optical rotation can easily be found in this way. If, in applying the torsion, the cylinder or crystal is subjected to bending, another liberation of electricity is produced which may interfere with the effects of the torsion. The writer concludes by remarking that the torsion effect is evidently distinct from the piezoelectric effect.

ERZEUGUNG UND UNTERSUCHUNG NICHTKRYSTALLINER PIEZOELEKTRISCHER STOFFE (The Formation and Investigation of Non-crystalline Piezoelectric Materials).—A. Meissner. (*Zeitschr. f. Tech. Phys.*, November, 1928, pp. 430–434.)

These materials are obtained by powdering the natural substance (*e.g.*, quartz crystals) and binding it together—while under the action of a strong electric field—with some substance such as colophonium (a sulphurated zinc product), beeswax, Canada balsam or pitch. These artificial plates possess strong pyroelectric as well as piezoelectric qualities—the latter (for quartz) being from 50–70 times as great as for the natural crystal plate. Unluckily the piezoelectric moment does not remain constant, falling to half its value in times which vary (according to the binding material used) from a day or two to several months. The most successful plate from this point of view was one of asphalt and quartz, which remained constant for six months. At present such a plate is not suitable for valve frequency control : its coefficient of elasticity is too low and its damping too high, But it can be used for a piezoelectric microphone.

about which there will be a further communication. The first part of the present paper deals with the pyroelectric behaviour of loose powders of various degrees of fineness.

THE TEMPERATURE COEFFICIENT OF QUARTZ CRYSTAL OSCILLATORS.—R. S. Strout. (*Phys. Review*, November, 1928, V. 32, pp. 829–831.)

The temperature coefficient of frequency of the plate used was found to decrease linearly from 22.7 parts per million per degree at 65 deg. C. to 1.6 parts per million per degree at − 189 deg. C.

OSCILLATION IN ULTRASONIC GENERATORS AND VELOCITY OF LONGITUDINAL VIBRATIONS IN SOLIDS AT HIGH FREQUENCIES.—R. W. Boyle and D. O. Sproule. (*Nature*, 5th January, 1928, V. 123, p. 13.)

The longitudinal, flectural and torsional oscillations of a quartz plate, with overtones of any or all of these, are further complicated when the plate is cemented to a metal rod or plate, as in ultrasonic generators. Examples are mentioned. Hence very cautious judgment must be exercised when determining a resonant frequency, particularly an overtone. However, with due caution the method may be used successfully to determine the velocity of sound in, and Young's modulus of, the rod at the frequencies of the fundamental note and lower overtones. The modulus for ice is easily determined by this method, whereas other methods appear to be unsatisfactory.

FREQUENCY STABILITY BY MAGNETOSTRICTION OSCILLATORS.—H. P. Westman. (*QST.*, November, 1928, V. 12, pp. 21–26.)

An article based on Pierce's paper in the *Proc. Am. Acad. Arts and Sciences*, V. 63, No. 1 (referred to in Abstracts, 1928, V. 5, p. 643).

A PORTABLE CRYSTAL-CONTROLLED TRANSMITTER. —D. J. Angus. (*QST*, October, 1928, V. 12, pp. 33–36, 78 and 80.)

THE FREQUENCY MEASUREMENT PROBLEM: APPLICATIONS OF THE MONITOR IN TRANSMITTER SETTING AND SIGNAL CHECKING.—R. A. Hull. (*QST*, October, 1928, V. 12, pp. 9–19.)

See also the same writer, under " Transmission." In the wavemeters described, the series-gap condenser based on principles expounded by Griffiths (see February Abstracts) is employed.

EIN NEUER SPANNUNGSWANDLER (A New Voltage-transformer).—A. Imhof. (*Bull. de l'Assoc. Suisse d. Élec.*, 7th December, 1928, pp. 741–750.)

For high tension measurements, the special non-inductive high resistance here discussed is used in place of the customary step-down voltage transformer, with economic advantages which grow rapidly for voltages above, say, 30 kV. The lower end is earthed through the primary of the instrument current transformer.

A SENSITIVE VACUUM TUBE VOLTMETER.—C. B. Aiken. (*Journ. Opt. Soc. Am.*, December, 1928, V. 17, pp. 440–450.)

A new type of voltmeter making use of the heterodyne principle, for the measurement of steady, single frequency voltages in the audio and lower radio frequency ranges. It has a linear characteristic and is extremely sensitive: by using the best type of galvanometer it would probably give about one division per microvolt. Measurements can be made of weak signals accompanied by a relatively strong noise background.

A USEFUL DESIGN OF TUBE-VOLTMETER.—W. F. Powers and G. W. Alderman. (*Journ. Opt. Soc. Am.*, November, 1928, V. 17, pp. 379–380.)

A lay-out is shown which gives, with one arrangement of switching and connection, the " slide-back " thermionic voltmeter described by Kirke (*E.W. & W.E.*, Feb., 1927): with a second, the Van Der Bijl arrangement; and with a third, the Moullin voltmeter circuit.

MESURE DES FRÉQUENCES (The Measurement of Frequencies).—F. Bedeau and J. de Mare. (*T.S.F. Moderne*, August, 1928, V. 9, pp. 469–485: Summary in *Rev. Gén. d. l'Élec.*, 8th December, 1928, V. 24, p. 198D.)

Description of a tuning fork of special steel, having a constant frequency in spite of temperature variations. The coil acting on one prong is in the grid circuit of the first valve of an L.F. amplifier; that acting on the other prong is in the plate circuit of the second valve: in this circuit there is also the primary of a transformer, the secondary going to the grid circuit of a separate valve, whose grid is negatively biased and whose plate is connected to an oscillating circuit linked to the rest of the apparatus by a dry battery. If the oscillating circuit is nearly tuned to a multiple of the fork frequency, it will emit waves of this harmonic. Using forks of frequency 800, 1,000, 1,200 and 1,500 p.p.s., the writers have obtained the 150th and 200th harmonics of these frequencies. The use of the apparatus is described for calibrating an instrument, by steps of 500 p.p.s., up to a frequency of 200 kc.; or for finding the fundamental frequency of a quartz oscillator. Also, by acting on the thickness of the crystal (maintained at a constant temperature) it is possible to make it oscillate at a frequency exactly corresponding to that of a known harmonic of the fork.

AN INSTRUMENT FOR THE PRODUCTION OF KNOWN SMALL HIGH-FREQUENCY ALTERNATING ELECTROMOTIVE FORCES.—B. S. Smith and F. D. Smith. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part I, pp. 18–28.)

A portable instrument is described, giving E.M.F.'s of 10–50 kc. frequency and 0.0076–15,000 microvolts magnitude. It is intended for the calibration of amplifiers and the measurement of the strength of wireless signals of long wavelength. The valve oscillator (Hartley circuit) forms one screened unit, and its coupling coil is connected by 6ft. of screened cable to the second screened unit—

an artificial line of series and shunt resistance elements: each shunt element carries $1/\sqrt{2}$ times the current carried by the preceding element, so that the magnitude of the E.M.F. at the output of the artificial line depends upon the position of a rotating switch which makes connection with one or other of the sections. From this second unit another 6ft. screened cable goes to the third unit, a signalling key (specially designed to avoid abrupt changes in the constants of the circuit, which would produce noises in the telephones), the screening of all three units being connected together and earthed. The receiving circuit used with the set is a coil tuned by a condenser and a six-valve high and low frequency amplifier with heterodyne. It is sensitive to an E.M.F. of 0.01 μV. induced in the coil, and the valve oscillator must not affect it at a distance of 6ft.: the screening provisions, therefore, are aided by the use of toroidal coils in the oscillator; these coils are wound with a re-entrant turn of the conductor running along inside the winding, to neutralise the field due to the toroid behaving as a one-turn coil. The core of the toroid is of compressed iron dust. It was found useful to screen the secondary from the electric field of the primary by a braiding of fine copper wires. In the subsequent discussion, Wilmotte suggested the use of large condensers in place of resistances, in the artificial line, for high frequencies.

Über die Messung der Gitter-Anode-Capazität von Schirmgitterröhren (The Measurement of the Grid-Anode Capacity of Screen-grid Valves).—E. Klotz. (*Telefunken Zeit.*, October, 1928, No. 50, pp. 34–38.)

The method described will, with normal components and precautions, measure a capacity of 1/10th mm. with a maximum error of two or three per cent. By further precautions and the use of a micrometer-screw adjustment of the standard condenser, greater accuracy is obtained.

Die Messung von Kapazitäten mit dem Überlagerungsverfahren (Capacity Measurement by the Heterodyne Method).—W. Weihe. (*Zeitschr. f. Hochf. Tech.*, December, 1928, V. 32, pp. 185–194.)

A convenient and satisfactorily accurate method is described, depending on the phenomenon of "pulling into tune" between two oscillating circuits. Various methods of application are discussed with a view to the application of the simpler approximate formula $\Delta f = \frac{f}{2C} . \Delta C$ in place of the more complex exact formula. In the case of the method depending on retuning the note circuit, where the approximate formula does not hold, another formula is obtained. For use with high frequencies (200–20 m. wavelength), which add so much to the value of the method, a condition is indicated under which the approximate formula can be applied, in spite of the effects of the self-inductance of the leads. Conditions for obtaining a good constancy of frequency are investigated. As an example of the method, the variation of the input capacity of a valve with the ohmic load of the output circuit and with the wavelength was measured, and the results shown to conform with theory. Frequency variations due to filament and anode voltage fluctuations were corrected by a suitable choice of reaction coupling and of the working voltages, and by the introduction of a capacity shunted by a resistance in the grid circuit. For the first hour or two of service, the valves showed a steady alteration of frequency, but after that the constancy was good; for a period of 15 minutes the alteration was only 1 Hertz for a wavelength of 204 m. For waves down to 20 m. the period over which such constancy could be obtained was considerably shorter, but was sufficient for the measurements by the process described.

Einige Messungen über die Hochfrequenzspannungen an der Eingangsseite von Empfängern (Some Measurements of H.F. Voltage at the Input End of Receivers).—M. v. Ardenne. (*Zeitschr. f. Hochf. Tech.*, December, 1928, V. 32, pp. 199–202.)

To determine what H.F. amplification is necessary to receive satisfactorily a given station on a given aerial it is necessary to know the voltage produced at the input end of the receiver. To measure this it is necessary first to amplify it with an H.F. amplifier whose magnification is known. After discussing the various difficulties, the writer describes his measurements of signals from various broadcasting stations, received on various aerials and frames; using a special aperiodic amplifier whose amplification performance was known (see his article, Abstracts, 1929, V. 6, p. 47) and his thermionic voltmeter (*ibid.*, 1928, V. 5, p. 405). Results on the local station, Berlin ($\lambda = 483.9$ m.), show the voltages measured on large and small aerials and on frames of different sizes. Results on distant stations are given, showing the variation with time of day, a five-minutes fading curve for Prague (290 km. distant) being particularly striking. The last diagram gives the measured voltages for about forty broadcasting stations, including English, Spanish and Italian, measured at Berlin: this table gives the mean value over six minutes, and the maximum and minimum values during the fading period: all these measurements being taken on the same evening, between 8 p.m. and midnight in October.

Ein Kurzwellenempfangsgerät zur Messung der Feldstärke (A Short-wave Receiving Apparatus for the Measurement of Field Strengths).—G. Leithäuser. (*Abstract in E.T.Z.*, 13th December, 1928, p. 1816.)

As in Ander's method, the deflection produced by the field is reproduced by a calibrated local sender on the same wave. Reception is on frames, with a perfectly symmetrical circuit of two valves for intermediate frequency amplification and valve voltmeter. The valves connected direct to the frame have shield grids and a particularly low "durchgriff" ($1/\mu$) of about 10 per cent.; in this way capacity reaction into the frames is avoided. The regulation of the local transmitter signals is done with a molybdenum-tube rectifier, acting as a resistance which can be varied between 5 and 10,000 ohms.

Smallest measurable field strengths are 6–7μV/m. On the roof of the G.P.O., Berlin, the field strengths

of short-wave transmitters in England and Australia are about $150\mu V/m$.

RECEIVER CHARACTERISTICS AND THEIR MEASUREMENTS.—V. D. Landon. (*QST.*, October, 1928, V. 12, pp. 23–30.)

Deals with the work of the inter-company committee set up by the Radio Corporation, G.E.C., and Westinghouse Company, in standardising test methods and apparatus.

A QUICK AND SENSITIVE METHOD OF MEASURING CONDENSER LOSSES AT RADIO FREQUENCIES. —R. M. Wilmotte. (*Journ. Sci. Inst.*, December, 1928, V. 5, pp. 369–375.)

Author's Abstract: "The method is essentially a substitution method in which an air condenser is substituted for the condenser being measured, the current being brought to the same value in the two cases by inserting a resistance in series. The success of the method largely depends on the construction of a suitable continuously variable resistance, of which a description is given. With careful use the method will give the value of the difference of the equivalent series resistance between the standard condenser and that under test to within 0.01 ohm, or even less when the circuit conditions are very good.

A number of results of condenser measurements are given, and it is shown that the effective series resistance R of the variable air condensers measured can, within the limits of experimental error, be represented by the equation $R = r + \frac{1}{aC^2f}$, where f is the frequency, C the capacity, and r and a are constants of the condenser. r appears to be the resistance due to bad contacts and leads inside the condenser. Results tend to show that with aluminium plates the constant r is liable to be unexpectedly large, although in many cases it is very small. Also, with ebonite, the value of a appears to decrease with humidity.

The advantages claimed for the method are its rapidity, facility of working, possibility of working down to a wavelength of at least 50 metres, its comparatively high sensitivity, and most important, its freedom from errors due to reaction back on to the source." Later on it is stated that the method is only suitable for the measurement of screened apparatus and could not be used for the measurement of coils, for instance, which are not usually screened. But elsewhere the case of an unscreened condenser is mentioned, in which the capacity currents would render the measurement unreliable (unless the capacity were of such magnitude that its impedance could be neglected in comparison with the impedance of the capacity to earth): here the difficulty was overcome by measuring with the condenser inside a screened box.

CAPACITY IN THE DRYSDALE'S BRIDGE.—S. S. H. Nagir and P. N. Sharma. (*Journ. Sci. Inst.*, December, 1928, V. 5, p. 392.)

The distribution of stout copper pieces in this bridge (specially designed to minimise inductance) has been found to include capacities not negligible in comparison with the very small capacities to be measured in wireless circuits: they may be as much as $220\mu\mu F.$, and are not constant, being (in one case) more than halved after eight months' interval.

SUBSIDIARY APPARATUS AND MATERIALS.

EIN FÜR PRAKTISCHE VERWENDUNG GEEIGNETES VERFAHREN FÜR SPANNUNGSREGELUNG AN GENERATOREN MIT HILFE VON HOCHVAKUUMRÖHREN (A Practical Method of Generator Regulation by High Vacuum Tubes).—N. A. J. Voorhoeve. (*Arch. f. Elektrot.*, 7th December, 1928, V. 21, pp. 228–243.)

The writer considers three-electrode valve methods (*cf.* February Abstracts) too complicated for practical use, and describes a method, satisfactorily employed at the Philips Eindhoven Works, which uses two-electrode valves whose filament-temperature is controlled by the generator load, the consequent plate current variations regulating the generator field.

DIRECT-CURRENT GENERATORS OF VERY HIGH VOLTAGE.—S. R. Bergman. (*Gen. Elec. Review*, November, 1928, V. 31, pp. 596–599.)

The machines described are of one special type, built in ratings of from 5 to 150 kW. for voltages 7,500–15,000 v., specially for the anode supply of transmitting valves. The field is an open-slotted sheet-steel structure with two windings: a compensating winding completely neutralising the armature reaction, in series with the armature winding and distributed evenly around the armature so as to oppose the reaction at each point, and an exciting winding: the two windings being in quadrature. The field slots are closed by magnetic wedges made of soft iron, cotton-covered wire woven into a cloth, dipped in a resin solution, then shaped and cured. They halve the core loss and reduce the noise. With these machines, owing chiefly to the complete neutralisation of armature reaction, a treble overload does not cause commutator sparking. They will stand accidental short circuiting not only momentarily but for a sustained time without flashing. Ripple (caused chiefly by the slotted armature) is minimised by a squirrel-cage of copper strips in the bottom of the field-slots; this reduces the ripple to ¼ of 1 per cent. of total current; shunt condensers reduce it still further to 1/100 of 1 per cent. Above 10,000 v., two armature windings (in series), each with a separate commutator, are used.

A NEW TYPE OF LOW FREQUENCY LOW VOLTAGE DISCHARGE IN A NEON LAMP.—G. R. Paranjpe and K. Sheshadriengar. (*Nature*, 22nd December, 1928, V. 122, pp. 959–960.)

The periodic flashes here described differ from the usual type; no variable condenser is required in the circuit, the voltages used are lower, the discharges are very slow (0.57 to 9.04 seconds) and their period can be varied at will. The *actual* value of the potential of the cathode (in addition to its potential relative to the anode) and the earthing of the outside of the bulb appear to be important factors.

DER NEONGAS-SPANNUNGSANZEIGER (The Neon Tube Voltage Indicator).—(*Bull. d.l'Assoc. Suisse d.Élec.*, 22nd November, 1928, p. 740.)

The ordinary incandescent pilot lamp has the disadvantages that if the filament breaks the indication is false and that in any case it wastes current. The Philips Company has therefore produced a neon pilot lamp, for A.C. or D.C. With the latter, it also acts as a pole-indicator.

A NEW DEVICE FOR THERMOSTAT CONTROL.—H. F. T. Jarvis. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part 1, p. 112.)

An arrangement is described which kept the temperature of a tank of water constant within 1/50 deg. centigrade for a fortnight. A large bulb full of toluol, immersed in the water, governs the level of a mercury column on which floats a glass cylinder controlling two alternative wire-mercury contacts, in circuit with solenoids which rock in opposite directions a relay switch controlling the heating circuit.

A SENSITIVE THERMO-REGULATOR.—D. H. Black. (*Journ. Sci. Inst.*, December, 1928, V. 5, pp. 376–377.)

A bi-metallic spiral-strip regulator, primarily designed for electrically heated air ovens; sensitivity is such that for a difference in temperature of 1 deg. C. the tip of the contact arm moves through about 1 cm. Constancy of temperature within 0.1 deg. C. is easily obtained: with special precautions this can be improved to 0.04 deg. C.

CATHODE RAYS AS A LABORATORY TOOL.—(*Science*, 9th November, 1928, V. 68, Suppt., pp. xii–xiii.)

A new form of tube is described due to Slack (Westinghouse Co.) in which the window of thin nickel is replaced by a bubble of glass, which may be one five thousandth of an inch thick and one inch in diameter. The method of formation is such that it automatically assumes its shape so that the air pressure afterwards is the same as that during its formation.

A PROPOS DE LA THÉORIE DES OSCILLOGRAPHES ET APPAREILS INDICATEURS (Concerning the Theory of Oscillographs and Indicating Instruments).—A. Blondel, and SUR LA THÉORIE MATHÉMATIQUE DES OSCILLOGRAPHES (The Mathematical Theory of Oscillographs).—N. Bogoliouboff and N. Kryloff. (*Comptes Rendus*, 19th November, 1928, V. 187, pp. 921–923 and 938–940.)

In the first paper, Blondel criticises the methods and conclusions of the second, which deals with his own theory and deduces from it certain conditions which should be observed in order to make the error of synchronisation as small as possible.

ON THE USE OF THE DUFOUR CATHODE RAY OSCILLOGRAPH.—Bekku, Narasaki and Miyamoto. (*Journ. I.E.E. Japan*, August, 1928, pp. 796–815.)

The results of a year's experience. In damp atmospheres there is an appreciable surface leakage from the cathode, resulting in unsteady focusing: a special chamber remedied this and also decreased the blackening of the cathode. It is concluded that the deflecting coils should be placed nearer to the cathode than the deflecting plates, to obtain better uniformity of the fields. A sweeping system (getting rid of the Dufour mercury contact) was devised.

CONSTANTS OF AN ELECTROMAGNETIC OSCILLOGRAPH.—A. E. Kennelly. (*Nature*, 29th December, 1928, V. 122, p. 1010.)

Summary of a paper in *Proc. Am. Phil. Soc.* When an oscillogram (taken by such instruments—including the electromagnetic type) is analysed into a series of Fourier components of different frequencies, a correction factor has to be applied to each, to eliminate the error due to inertia: the magnitudes of these corrections depending on the particular frequency. A new, quick method for determining these factors is described: the instrument constants whose measurement is required are the resonant frequency, the specific deflection (deflection per unit of testing current taken at some convenient reference-frequency, such as 60), and the "bluntness of resonance" (reciprocal of the sharpness).

EIN MESSKONDENSATOR FÜR HOCHSTSPANNUNGEN (A Test Condenser for Extra High Tensions).—R. Vieweg and H. Schering. (*Vortragshandbuch*, 90 Versamm. d. Ges. Deut. Nat. forsch., Hamburg, September, 1928.)

A compressed gas condenser in which the electrodes are built into an insulating case capable of withstanding the gas pressure: a leading-in insulator is thus dispensed with. A simple screening of the L.T. electrode gives freedom from loss and a constant capacity. The first of its kind has stood 350 kV. perfectly and has been used for measuring purposes up to 300 kV. The principle allows condensers to be made for much higher voltages still.

THE PHYSICAL SOCIETY'S ANNUAL EXHIBITION.—(*Wireless World*, 23rd January, 1929, V. 24, pp. 106–108.)

Among various exhibits of radio interest may be mentioned the McLachlan-Sullivan modulated C.W. wavemeter, in which a screened-grid valve working on the negative resistance part of the characteristic is connected with radio- and audio-frequency circuits so as to generate modulated H.F. without any reaction coupling: and an inductance for standard wavemeters wound on a former of such material that the diametrical and axial thermal expansions compensate in their effects.

AN IMPROVED ROSA CURVE TRACER.—H. E. Bonn. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 207–223.)

The improved form is smaller, simpler, and more accurate than the original type invented 30 years ago and relegated to the background by the various oscillographs. The instrument has the advantage, for the recording of the wave-form of A.C. generators, over moving coil or cathode-ray oscillographs in "greater sensitivity, remarkable accuracy and

extreme simplicity." It will, for example, work in practically any circuit, of high or low impedance, where a voltage of 0.1 V. or even less is available: giving large records (examples are shown) with a very thin trace. It works by a personally operated point by point method, the galvanometer being brought to zero by a potentiometer adjustment and a "dot" formed on the record by pressing the "printing lever": the release of this lever moves on the cylinder by a desired amount. A complete wave-form takes a few minutes to plot.

Über ein hochempfindliches Messinstrument für Wärmestrahlung (A highly sensitive measuring instrument for heat radiation).—G. Hettner. (*Zeitschr. f. Phys.*, 6th March, 1928, V. 47, pp. 499–508.)

Describes a new design of radiometer greatly exceeding in sensitivity all previous types.

Device for Regulating a Physical Phenomenon according to a Curve determined in advance.—(French Patent No. 641,232, Arnoux Chauvin and Co., published 30th July, 1928.)

A rotating insulating cylinder covered with a conducting layer has the predetermined curve cut in this layer so as to divide it into two parts insulated from each other. A needle pressing on the cylinder controls, through relays, the physical process in question.

Über punktförmige Aufnahmen von Wechselstromkurven insbesondere bei höherer Frequenz (Point by Point Plotting of A.C. curves, especially at Higher Frequencies).—F. Eisner. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 473–502.)

The usual methods using the Joubert Disc fail at high frequencies. The writer, by the use of phase-changers and of valve circuits, has extended the same principle to frequencies of 8,000 cycles per sec., and is trying to reach 150,000.

A Portable Electric Harmonic Analyser.—(*Journ. Sci. Inst.*, October, 1928, V. 5, pp. 320–323.)

An instrument depending on the dynamometer principle that a steady deflection can only be produced by currents of the same frequency in the fixed and moving coils. A current related in some known way to the voltage or current to be analysed is passed through the moving coil, while through the fixed coil is passed a sinusoidal analysing current from a synchronously driven contact disc and a valve circuit.

Stromrelais mit geringem Eigenverbrauch (Current Relay with Small Consumption).—(*E.T.Z.*, 1st November, 1928, p. 1615.)

Illustration and brief description of a Siemens and Halske relay working on 0.1 volt-ampere, and controlling up to 10 VA. A special point is that by turning a knob the operating current can be doubled or halved and the relay adjustment will adapt itself to the new conditions.

Erfahrungen mit Aluminiumleitungen (Experience with Aluminium Conductors).—(*E.T.Z.*, 25th October, 1928, pp. 1581–1582).

Einfluss der Luftfeuchtigkeit auf den Überschlag von Isolatoren (Influence of atmospheric humidity on the Flash-over of Insulators).—W. Weicker. (*E.T.Z.*, 15th November, 1928, p. 1696–1697.)

A letter discussing the author's results and those of Littleton and Shaver in America, and of Schwaiger.

Magnet Cores.—(German Patent 460,645, Siemens and Halske, published 4th June, 1928.)

The use of spongy iron is specified, which for example is ground up, mixed with insulating material, and compressed.

Perfectionnement aux Rectificateurs Électriques à Contact (Improvements to Contact Rectifiers).—Westinghouse El. & Mfg. Co. (*Rev. Gén. de l'Élec.*, 24th November, 1928, V. 24, p. 186D.)

A summary of a patent recently published, describing the thermal processes used in the manufacture of these oxide rectifiers.

Megavox Eliminator: an H.T. Eliminator for A.C. Mains with Metal Oxide Rectifier of Universal Application to Receivers with Three and Four Valves. Part. I.—W. I. G. Page. (*Wireless World*, 12th December, 1928, V. 23, pp. 787–791.)

"Motor-boating, distortion and hum are entirely absent and a generous output of 100 mA. at 200 v. is obtainable."

Surges in Eliminator Smoothing Circuits.—(*E.W. & W.E.*, December, 1928, V. 5, pp. 680–682.)

Correspondence on Warren's article (*ibid.*, November, 1928). It is suggested that in many cases matters are not so bad as the analysis might lead one to believe, and that simple safety devices, neon surge absorbers, etc., exist which remove such troubles as there may be. The author of the article replies.

STATIONS, DESIGN AND OPERATION.

Die Fernsprechverbindung zwischen Europa und Amerika (The Telephony Link between Europe and America).—E. Wollner. (*E.N.T.*, December, 1928, V. 5, pp. 489–522.)

A very full description of the London-New York system with photographs, diagrams of connections, curves (*e.g.*, of daily variations in interference and in the ratio signals to interference), lay-out of directional aerial systems, etc., etc.

Ein neuer Rückkopplungssperrer (A New Reaction Suppressor).—W. Hahn and H. Warncke. (*E.N.T.*, December, 1928, V. 5, pp. 522–529.)

After describing the complications—reaction and echoes—which make their appearance when a wireless line of communication is extended to a land-line system, and explaining how the precautions which are satisfactory in 4-line telephone practice (artificial balancing lines, etc.) fail in such a case, the writers outline the methods of reaction-suppressing used in the England-America

service; fundamentally similar in the two countries, though at the American end mechanical relays are used, while at the English end a shift of grid-potential is employed. They then describe the simpler methods which can be used where two different wavelengths are employed for the two directions: even in this case, the rather complex "double-actuated" arrangement (*i.e.*, actuated both by the transmitting and the receiving systems) must be used if the plan is adopted of leaving the receiving path open and the transmitting path closed during the state of rest. But if the receiving path is blocked and the transmitting path left open, a simpler circuit can be used ("singly actuated suppressor") which has the advantage, among others, that the listener hears no interference during the pauses of speech—with the subjective result that he gets the impression that there is no interference, and consequently hears better. The rest of the paper deals with the German Post Office's Magnetron-operated system working on this principle, and said to combine the advantages of the grid potential-shift and the mechanical relay systems. Three-electrode valves are used, connected for amplification, the degree of amplification being controlled by the magnetron-winding. Thus the control circuit is electrically disconnected from the controlled circuit: while the "relay" is inertialess as compared with a mechanical relay.

HÖRBARKEITSGRENZEN UND GÜNSTIGSTE VERKEHRSZEITEN BEI KURZWELLEN AUF DEN EINZELNEN ÜBERSEELINIEN (Limits of Audibility and Most Favourable Traffic Times for Short Waves over various Trans-oceanic Routes).—E. Quäck and H. Mögel. (*E.N.T.*, December, 1928, V. 5, pp. 542–549.)

A series of elaborate coloured tables is given (based on measurements made at Geltow) showing the most favourable times and the limits of audibility, in dependence on time of year and time of day, for the various short-wave routes from Berlin to New York, Buenos Aires, Rio de Janeiro, Mukden, Bandoeng, Manila, Sydney and Bangkok. Echoes (direct and reverse) are also indicated. Each route is dealt with descriptively in a separate section. The waveband 10–40 m. is divided into three channels—day waves 10–18 m., transition waves 19–24 m., night waves 25–40 m. In general, a day and a night wave is enough for a 24-hour service: for certain routes the intermediate wave is necessary. Various interesting points are discussed: in the Berlin-Sydney route during the daylight period of the direct route, transmission is best by the reverse route, which has 20,000 km. in darkness: directional aerials and screens would have therefore to be reversed.

ÜBER PROBLEME BEIM BAU MITTLERER UND KLEINER SENDESTELLEN (Problems connected with the Construction of medium and small Transmitters).—v. Behringer and Graf. (*Telefunken Zeit.*, October, 1928, No. 50, pp. 16–21.)

An article on the preliminary calculations connected with the design of transmitters; the particular case taken being a long wave overland telegraphy set of power of the order of 5 kW. Curves relating to distance, height of masts, etc., are given.

NAUEN TO BUENOS AIRES: A DESCRIPTION OF THE SHORT-WAVE BEAM TRANSMITTING STATIONS. —(*Wireless World*, 16th January, 1929, V. 24, pp. 73–74.)

"The telephony service on short waves was opened on December 10th last. Each transmitter has a power of 20 kW., while the wavelengths are 14.83 and 15.34 m." The article is based chiefly on papers from the Telefunken staff (*cf.* Abstracts, February, 1929, under "Aerials") read at the meeting of German scientific workers last year. Esau's opinion that hollow mirrors, especially if made with a continuous metal surface, would give better directional effect than the flat aerials used, was not supported by the Telefunken engineers, who maintained that the directional effect with the latter was so sharp that no improvement in this direction was necessary.

Runge's receiver (for telephony and high-speed telegraphy) for wavelengths down to 10 m. is mentioned: it has four neutralised H.F. stages giving an amplification of about 500, followed by intermediate-frequency amplification of some 20,000—giving a total H.F. amplification of about a million.

DIE NEUE FLUGHAFENSENDERANLAGE IN ASPERN (The new Air Station Transmitter at Aspern). —R. Linsmayer. (*Suppt. to Elektrot u. Masch: bau*, No. 11, 25th November, 1928, pp. 97–101.)

Description of the new installation near Vienna, for C.W. and tonic train telegraphy and for telephony: input to aerial 3 kW. on a long dash. Wave range 600–3,600 m.

POSTE À ONDES COURTES TYPE H.C.8 POUR HYDRAVIONS ET AVIONS (Short Wave Set Type H.C.8 for Seaplanes and Aeroplanes). —(*Bull. d. l. Soc. Fr. Rad.*, November, 1928, pp. 13–20.)

For C.W. and I.C.W. telegraphy. Wavelengths (transmission) 50–60 m.; (reception) 45–65 m. Power to aerial 50–75 W. Total weight including converter, batteries, and wiring about 95 lbs.

POSTE À ONDES COURTES, TYPE A.C.1 (Short Wave Set, Type A.C.1.).—(*Bull. d. l. Soc. Fr. Rad.*, October, 1928, pp. 8–17.)

Illustrated description of 15–60 m. transportable set (receiver 10–100 m.) giving 40–45 watts to the aerial. Telegraphy only is provided for. Weight of transmitter about 34 lbs., of receiver 11 lbs.

LES CODES MÉTÉOROLOGIQUES (The Meteorological Codes).—(*QST Franç.*, November, 1928, pp. 8–15.)

First part of an article dealing with the subject. Tables show names and positions of the principal transmissions of meteorological observations (Meteo-regional, Meteo-France, and the international Meteo-Europe and Meteo-America), their call numbers and hours, the nature of the information and the symbolic form in which it is given.

BROADCASTING IN CANADA.—(*Nature*, 29th December, 1928, V. 122, p. 1006.)

A "News and Views" paragraph on a paper in the *Canadian Magazine*, which says that broadcasting in Canada is almost in chaos: there is not a single station in the United States or Canada which exists purely for the purpose of entertaining the public: all have ulterior motives of self-interest. The possibilities of a new system are discussed: the English system would be inapplicable because of the great differences in time across Canada; the language difficulty also is a very real one. Two main stations, one in eastern and one in western Canada, each with a train of relay stations, are suggested. The main difficulty is the financial one, and the only solution appears to be a sound, businesslike development of the advertising field.

In connection with the above, a paragraph in *The Wireless World*, 19th December, is of interest. Members of a Royal Commission appointed in Ottawa are to tour Britain, France and the U.S.A. to gather data on the respective merits of State and privately owned Broadcasting. "It is believed that the Canadian Authorities favour a system designed on B.B.C. lines."

LES PROGRÈS DES COMMUNICATIONS TÉLÉGRAPHIQUES ET TÉLÉPHONIQUES EN ALLEMAGNE (Progress in telegraphic and telephonic communication in Germany).—(*Génie Civil*, 29th December, 1928, V. 93, pp. 637–639.)

This article includes a map giving the broadcasting stations, principal and secondary, with their lines of communications (cable or overhead line).

LA STATION DE LA TOUR EIFFEL (The Eiffel Tower Station).—G. Martin. (*QST. Franç*, November, 1928, pp. 25–36.)

DIE ENTWICKLUNG DES RUNDFUNKS IN ÖSTERREICH (Broadcast Development in Austria).—(*Suppt. to Elektrot u. Masch: bau*, No. 11, 25th November, 1928, pp. 103–104.)

WHO'S WHO IN THE ETHER.—J. G. Abrahams. (*Wireless World*, 2nd January, 1929, V. 24, pp. 7–12.)

"A guide to the identification of distant transmissions." Among other hints, the cuckoo call of Ljubljana and the musical-box nine-chord tune of Budapest are mentioned.

AMPLITUDENBEGRENZER FÜR PROGRAMMÜBERTRAGUNG (Amplitude Control for Transmission of Programmes).—H. F. Mayer. (*Summary in E.T.Z.*, 13th December, 1928, p. 1816.)

The upper limit is best done at the last stage of the main amplifier. Here the charge of a condenser shifts the grid-potential of the preceding valve, so that the condenser voltage cannot increase beyond the voltage of the lower bend of the characteristic. The final value of voltage is reached in about 0.01–0.02 sec., so that only for such a time can the last valve be over-controlled. The discharge time for the regulating condenser is about 2 minutes.

LAUTSTÄRKEREGELUNG (Volume Control).—H. Ziegler. (*Telefunken Zeit.*, October, 1928 No. 50, pp. 21–24.)

Automatic control methods (*e.g.*, in broadcast transmission, to avoid sudden over-modulation) have the weak point that they flatten down the transmission. The present paper deals quantitatively with non-automatic shunt controls, applied in front of the first amplifier valve; a non-inductively wound variable resistance across the primary of the input transformer is shown to be preferable to a variable resistance across the secondary winding.

GENERAL PHYSICAL ARTICLES.

THE UNIVERSE AND IRREVERSIBILITY.—(*Nature*, 24th November, 1928, V. 122, pp. 808–809.)

Correspondence on Jeans' lecture (January Abstracts). J. B. S. Haldane points out that if Jeans' premises are correct, it is consistent to deduce that there is no need to assume a break in the order of Nature to account for the beginning of the present universe: if the present universe melts away into radiation, another equally improbable one will develop in the course of $10^{10^{100}}$ years. But it is perhaps unlikely that even a single atom will be built up from radiation in inter-galactic space during the "life" of the present universe.

THE AVERAGE LIFE PERIOD OF AN ATOM.—J. H. J. Poole. (*Nature*, 22nd December, 1928, V. 122, p. 960.)

Referring to Jeans' hypothesis as to the ultimate fate of atoms, the writer refers to data on the observed energy flow from the earth's surface, and deduces that the complete life of a terrestrial atom must be at least 10^{21} years: so enormous compared with the estimated age of the universe that we should be justified in treating our atom as eternal. A following letter from Jeans agrees with the above conclusions and refers to similar statements in his own publications.

NEUE UNTERSUCHUNGEN ÜBER DIE DURCHDRINGENDE HESSCHE STRAHLUNG (New investigations of the penetrating Hess radiation).—E. Steinke. (*Zeitschr. f. Phys.*, 14th May, 1928, V. 48, pp. 647–689.)

NUCLEAR DISINTEGRATION. — Kirsch, Pettersson, Bothe and Fränz (*Nature*, 15th December, 1928, V. 122, p. 939.)

A paragraph on the argument between the first pair of workers (Vienna) and the second (Berlin) as to the interpretations which should be placed on their respective experiments on artificial disintegration.

MEASUREMENTS OF THE VELOCITY OF SOUND IN AIR, NITROGEN AND OXYGEN, WITH SPECIAL REFERENCE TO THE TEMPERATURE COEFFICIENTS OF THE MOLECULAR HEATS.—W. G. Shilling and J. R. Partington. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 920–939.)

The molecular heats of air, nitrogen and oxygen

have been determined over a temperature range 0 deg. C. to 1,000 deg. C. by a method depending on the measurement of the velocity of sound in the chemically pure gases. Further measurements for air up to 1,300 deg. C. are added.

THE BALLISTIC METHOD OF IONISATION MEASUREMENT WITH A QUADRANT ELECTROMETER.—D. L. Webster and R. M. Yeatman. (*Journ. Op. Soc. Am.*, September, 1928, V. 17, pp. 248–253.)

AN APPARATUS FOR THE MEASUREMENT OF RADIATION INTENSITY OVER A WIDE RANGE OF WAVELENGTHS (0.02 — 3 Angstrom).—O. Glasser and V. B. Seitz. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 240–247.)

A condenser unit, with electrometer attached, is charged to a known potential, after which it is removed and placed with its ionisation chamber in the field of radiation for a specified time. A second electrometer-reading is then taken, and from the loss of charge the intensity of radiation is found.

RECOMBINATION OF IONS IN THE CHAMBER OF AN X-RAY SPECTROMETER.—D. L. Webster and R. M. Yeatman. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 254–259.)

ROTATION OF MOLECULES INDUCED BY LIGHT.—C. V. Raman and K. S. Krishnan. (*Nature*, 8th December, 1928, V. 122, p. 882.)

Compounds which have a strong optical anisotropy (*e.g.*, benzene) exhibit the "wings" or nebulosity (accompanying the original lines of the mercury arc after scattering) to a very much greater degree than compounds much more nearly isotropic (*e.g.*, alcohol). This supports the writers' earlier suggestion that these "wings" are the effect of those collisions of the incident light-quanta with the molecules which result in a change of their rotational state. It appears reasonable to suppose that the probability of a spin being set up should depend (among other factors) on the degree of optical anisotropy.

FREQUENCY CHANGE IN SCATTERED LIGHT.—F. A. Lindemann, T. C. Keeley and N. R. Hall. (*Nature*, 15th December, 1928, V. 122, p. 921.)

Preliminary results are announced of work on the Raman effect using a plane polarised beam. The results would be explained if it were assumed that a polarised quantum can only interact with a linear oscillator if the plane of polarisation is perpendicular to the line in which oscillation occurs, and that it is re-radiated polarised parallel to this line.

THE SCATTERING OF X-RAYS FROM GASES.—C. S. Barrett. (*Phys. Review*, June, 1928, V. 31, pp. 1119–1120.)

X-RADIATION FROM GASES.—A. Björkeson. (*Nature*, 7th July, 1928, V. 122.)

The writer has, after many failures, succeeded in obtaining X-rays from gases—by directing a beam of electrons on to sodium vapour and sulphur vapour.

ATOMIC MAGNETISM.—K. Honda. (*Nature*, 1st December, 1928, V. 122, p. 858.)

A summary of Honda's account of his theory of the origin of magnetism in the September issue of the *Science Reports of the University of Sendai*. He shows that it explains many facts not covered by previous theories. He considers the atom to consist of a number of orbital electrons equal to the atomic number of the element, and a nucleus containing additional electrons equal in number to the difference between the atomic weight and the atomic number. Just outside these latter electrons a number of protons revolve in the opposite direction. The outer electrons cannot be magnetised by an external field, but the processional motion produced gives rise to the diamagnetism of the atom. In ferromagnetic atoms the magnetic moment of the nuclear electrons and protons nearly cancel each other and the atom is easily turned by an external field. In paramagnetic atoms, neutralisation is less complete and the external field has less effect. In diamagnetic atoms the magnetic moment is large and the field produces no effect on it, the diamagnetism being due to the outer electrons.

ON THE MAGNETISATION OF SINGLE CRYSTALS OF IRON AT HIGH TEMPERATURES.—K. Honda, H. Masumoto and S. Kaya. (*Sc. Rep. Tôhoku Univ.*, No. 2, 1928, V. 17, pp. 111–130.)

THE UNDERSTANDING OF RELATIVITY. (*Nature*, 2nd November, 1928, V. 122, pp. 673–675.)

Nine years have passed since the historic meeting at the Royal Society when the British eclipse expedition announced the confirmation of Einstein's prediction, from the general theory of relativity, that starlight would be deflected by the gravitational field of the sun. The silent, matter-of-fact way in which relativity has since then been absorbed into the general scheme of physics is remarkable, but the attempt to express relativity in ordinary language so that the general public may absorb it represents the most conspicuous failure of modern scientific exposition. The present article points out some of the ways in which such attempts have failed, and suggests how future methods of exposition can be improved.

THE UNDERSTANDING OF RELATIVITY. (*Nature*, 24th November and 15th December, 1928, V. 122, pp. 808 and 925.)

Correspondence on the article referred to above, including a letter (p. 925) from L. Bolton, who (as the Editor remarks) was awarded the big "Scientific American" prize in 1921 for the clearest explanation for general readers. On p. 934 there is also a "News and Views" paragraph on the subject.

PRODUCTION AND PROPERTIES OF HIGH-FREQUENCY RADIATION.—E. Rutherford. (*Nature*, 8th December, 1928, V. 122, pp. 883–886.)

From the presidential address delivered at the anniversary meeting of the Royal Society. The gap in frequency between ordinary ultra-violet light and soft X-rays has been bridged in the last few years. There appears to be no limit to the

frequency that can be obtained by the bombardment of matter with electrons—other than the practical difficulty of obtaining streams of the requisite high velocity electrons. About a million volts have been successfully applied for a short time to an X-ray tube. The X-rays obtained were of such intensity and penetrating power that they could easily be observed by the luminosity on a phosphorescent screen 100ft. away.

But no X-ray has yet been produced to equal the γ-rays in penetrating power. The Einstein equation $E = mc^2$ is then dealt with, in connection with the energy-emitting transformations of radioactive bodies; the loss of energy (27,000,000 electron-volts) in the process of building a helium nucleus from free protons and electrons, and that in building a mercury atom (1,400,000,000 electron-volts) suggest that the formation of the simple helium nucleus may be one of the sources of energy radiation from the stars: and that the heavy and complex nucleus of mercury, *e.g.*, is unlikely to be built up in one act. Jeans' supposition, that the protons and electrons themselves are not indestructible, but may be transformed into radiation, is discussed. If the proton and electron disappeared together, with the liberation of one single quantum of energy, we should expect to obtain a γ-radiation corresponding to about 940,000,000 volts.

After classifying such a hypothesis as of a very speculative nature and possibly very difficult of direct proof or disproof, the writer agrees that the long life of the hot stars seems to demand some such process where the liberation of energy is enormous compared with the mass involved. "It is thus of very great interest to examine whether any direct experimental evidence can be obtained of the existence of such extraordinarily energetic γ-rays." This leads to a discussion of the ultra-penetrating radiation first observed by Hess and Kolhörster. The absorption coefficient of the most penetrating type of this radiation, deduced by Millikan and Cameron, is in excellent accord with that to be expected on the Klein-Nishina theory for a quantum of energy 940,000,000 volts: but, "although this agreement is suggestive, our theories of absorption are at present too uncertain to place much weight upon it." Also it should be remembered that the ultra-penetrating radiation may not be high-frequency γ-rays, but high-energy electrons entering our atmosphere. The paper concludes by pointing out the need for further information before we can draw any but tentative conclusions. So far, experiments have been mainly confined to measuring the ionisation produced in a sealed electroscope: experiments are needed analogous to those of Skobelzyn (on the relative intensities of the main γ-rays from radium *C*), using a Wilson expansion chamber. The β-particles produced by the penetrating radiation could also be counted by a Geiger counter.

MISCELLANEOUS.

Method and Apparatus for the Measurement of Distances by the Use of Electromagnetic Waves.—(*British Patent No.* 288,233, Koulikoff and Chilowsky, acc. 6th September, 1928.)

To determine the distance between *A* and *B*, waves from *A* having a frequency of N_1 are received at *B* by a circuit tuned to N_1: they are amplified and may be rectified. The rectified current acts upon the grid of the oscillating circuit of a transmitter *B'* (close to *B*) and causes this transmitter to transmit waves of frequency N_2, which are received by a receiver *A'* (close to *A*) tuned to that frequency, and after amplification and perhaps rectification are used to act on the transmitter *A*. Thus a succession of trains of waves are obtained whose period (which can be measured by a wavemeter) gives the distance between *A* and *B* by the formula $d = \frac{c}{2N_m}$. Another variation of the method uses the same frequency at the two stations instead of the different frequencies N_1 and N_2.

Radio Altitude Gauge. (*Science News Letter*, 24th November, 1928, V. 14, p. 317.)

Alexanderson described, before the Nat. Acad. Science (November 19th-21st, 1928), a method of using the reflection of radio waves back to an aeroplane from the ground as a method of measuring the height of the aeroplane: "by the effect of the returning wave on the actual transmitter: this effect is to change the wavelength of the transmitted wave, and so it affects the strength of the returning wave. Thus by measuring this strength of the returning wave and the number of changes in step, the distance is determined." He also suggested the use of two oscillators of slightly different frequency, which could be arranged to light a green lamp when the aeroplane was at 240 feet and a red lamp at 80 feet. *Cf.* Koulikoff and Chilowsky, above.

Alarm Altimeter.—(*Scient. American*, June, 1928, p. 551.)

Photograph of a device for use in ballooning: when the balloon approaches the ground too closely for safety, a light flashes and a buzzer sounds.

Les Ondes ultrasonores (Supersonic Waves).—S. Weil. (*Revue scientif.*, 13th October, 1928, V. 66, pp. 590–596).

An account of the work of Wood, Richard and Loomis on the generation of these waves and on their physical, chemical, thermal and physiological actions.

The Sound Rangers.—G. E. Moore. (*Electrician*, 9th November, 1928, V. 101, p. 517.)

"Being memories of a little-known Technical Unit at the Front—Some Applications of Electricity in the Great War—Importance of the Hot-wire Microphone."

La T.S.F. et la Stratégie Navale Britannique (Wireless and British Naval Strategy).—Commandant X —. (*QST. Franç.*, November, 1928, pp. 47–52.)

This article, based on the publication entitled "British Official Wireless Messages to Merchant Ships," begins by a lengthy analysis of Lord Jellicoe's "Naval Policy of the Empire" in the 1926 *Naval Annual*.

Ray of Death—and Life.—(*Daily Express*, 9th January, 1929.)

The Berlin correspondent reports an interview with Esau on the subject of his cigar-box-sized transmitter for wavelengths below 3m. "Flies and insects which pass across this field drop dead. Mice are killed in a few seconds. . . . If we succeed in perfecting our apparatus we shall be in a position without in any way injuring the tissue to kill disease-causing bacteria within the human body." *Cf.*, Abstracts, 1928, V. 5, p. 640.

Burglar Alarm, etc., Depending on the Variation of an Oscillating Circuit.—(French Patent No. 644354, Laboureur and Briot, published 6th October, 1928.)

The action of the burglar upsets the tuning of the grid circuit of an oscillating triode, and thus causes a large change of plate current which works a relay.

Acoustic Marine Sounding.—(French Patent No. 641969, Marti, published 14th August, 1928.)

A fixed electromagnetic oscillograph actuated by one single microphone records the sound wave as it is emitted and as it returns after reflection; by a suitable arrangement of distances, the microphone retains its sensitivity after the first (large) impulse so that it can record the second even if this arrives a very short time later.

Vacuum Tube Synchronising Proves Advantageous.—(*Elec. World*, 17th November, 1928, V. 92, p. 996.)

A small coupling condenser with two stages of low frequency amplification has been used for synchronising, at an American hydro-electric plant, with great success for over a year. Maintenance cost has been practically zero, and the method dispenses with the high-voltage transformers, fuses, etc., usually needed for the operation of a synchroscope.

Apparatus for the Generation of Electricity. M. E. L. M. Rolot. (French Patent No. 642771, published 4th September, 1928.)

Molecules of oxygen or of ozone, at pressures of the order of 100 kg/cm², finding themselves in the magnetic field of a magnet are put in motion and traverse one or more solenoids, in which they produce induced currents.

Über ein neues Prinzip zur Herstellung hoher Spannungen (A New Principle for the Production of High Voltages).—R. Wideröe. (*Arch. f. Elektrot.*, 17th December, 1928, V. 21, pp. 387–406.)

An investigation of the possibilities of using electrons or ions to generate very high voltages (*cf.* French Patent, above). Theoretically there are two methods, one in which the electrons are compelled to rotate in an electrical rotating field, the other in which they (or the ions) are accelerated in several potential fields one after the other. The former method is dismissed for the present as too difficult, but the latter is worked out in detail and actually tried on a small scale. Ions are more practicable than electrons owing to their lower speeds.

Increase in Conductivity of Glass under Electron Bombardment.—W. R. Ham, M. H. White and H. R. Kiehl. (*Phys. Review*, June, 1928, V. 31, p. 1128.)

Neue Starklichtlampen mit Wolfram-Einkristall (New High Candle-power Lamps with Single-crystal Tungsten Filaments).——. Salmony. (Summary in *E.T.Z.*, 20th December, 1928, p. 1855.)

After describing the known processes for obtaining single-crystal filaments, the writer deals with a special form of tungsten filament (covered by German Patent No. 459651). Filaments of various shape can be used. With one form of filament, the consumption is 0.45W. per Hefner Candle (1 HK = 0.9 Candle). A spherical-spiral form gives a light density of 1700–1800 HK per cm². These filaments give reduced sputtering and consequent blackening.

Radio-Telegraphy and Radio-Telephony: a Review of Progress.—E. B. Moullin. (*Journ. I.E.E.*, January, 1929, V. 67, pp. 170–176.)

Talking Films No. 2. The British Acoustic Film System.—(*Wireless World*, 26th December, 1928, V. 23, pp. 842–844.)

Le V^e Salon Annuel de la T.S.F. (The 5th Annual Wireless Exhibition).—(*Rev. Gén. de l'Élec.*, 1st and 8th December, 1928, V. 24, pp. 821–827 and 868–873.)

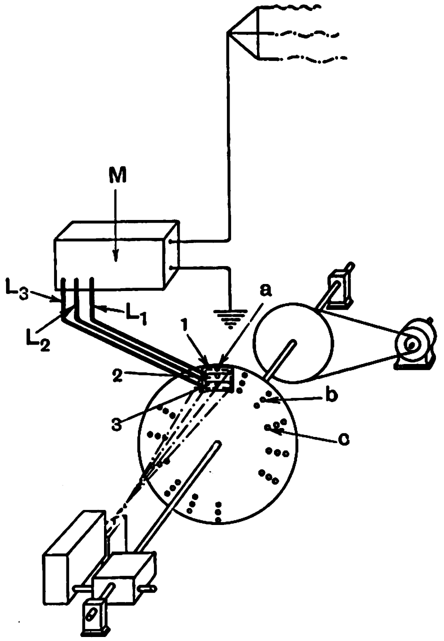
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

TELEVISION APPARATUS.

(*Application date, 8th June,* 1927. *No.* 298255.)

In order to reduce the speed of the rotating "scanning" discs used for transmitting and receiving animated visual effects, three or more



separate sets of spirally-staggered holes *a, b, c* are used to analyse simultaneously three distinct segments 1, 2, 3 of the object being televised. The elative setting of the spiral series of holes *a* is such that in each rotation of the disc they completely traverse the segment 1. Similarly the series *b* and *c* traverse the segments 2 and 3.

Separate frequencies are used for each segment and are fed along leads L_1, L_2, L_3 to the modulating apparatus *M*. A similar synthesising disc is used at the receiving station. Small light-sensitive cells may be fitted in each hole in the transmitter disc, each cell being connected to an insulated slip-ring from which the leads L_1, L_2, L_3 are fed through brushes. At the receiving end the spiral holes may be replaced by small neon lamps.

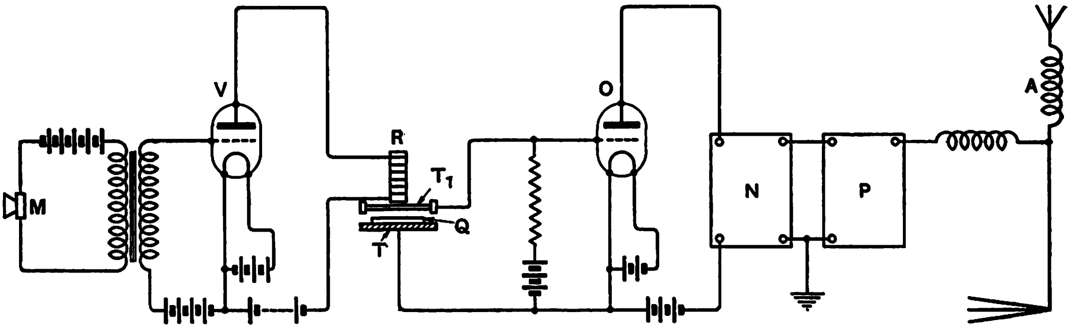
Patent issued to R. L. Aspden.

SIGNALLING BY FREQUENCY MODULATION.

(*Convention date* (*U.S.A.*), *17th March,* 1927. *No.* 287459.)

When transmitting music and speech on an ordinary or amplitude-modulated carrier, the attendant side-band frequencies usually extend over some 16,000 cycles. By utilising a system wherein the amplitude of the carrier is maintained constant, but its frequency is made to vary in sympathy with the applied low-frequency signals, the width of the side-bands is stated to be reduced to a few hundred cycles only, thus lessening the risk of overlap in areas where the available ether space is overcrowded.

The transmitting circuit is shown in the Figure. Signal current from the microphone *M* is applied to an amplifier *V*, in the plate circuit of which is an electromagnet *R*. A piezo-crystal *Q* is mounted between a fixed electrode *T*, and a movable electrode T_1 vibrated by the amplified currents passing through the electromagnet *R*. The piezo-crystal is located in the grid circuit of an oscillation-generator *O*, the output of which therefore varies in frequency according to the movements of the armature-electrode T_1. The frequency-modulated output from o is then passed through a frequency-multiplier *N*, and power-amplifier *P* to the transmitting



aerial *A*. At the receiving end a highly resonant circuit is adjusted slightly off the mean carrier-frequency, and detection is effected by the travel

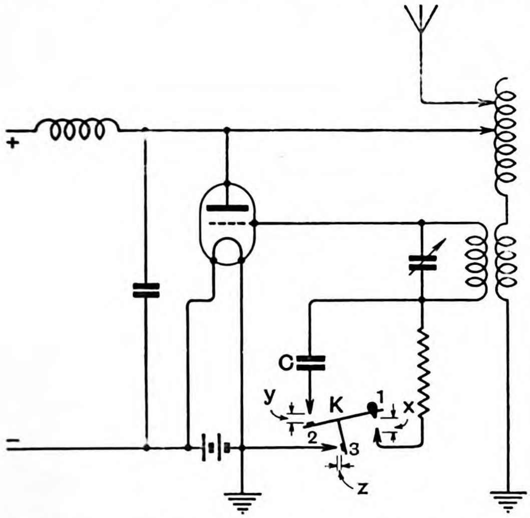
of the incoming signal-voltages along the slope of the resonance curve.

Patent issued to Westinghouse Electric and Manufacturing Co.

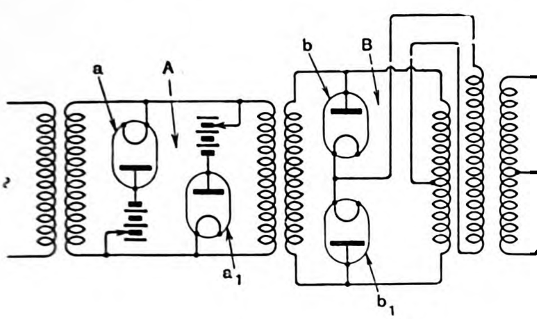
HIGH-POWER KEYING.

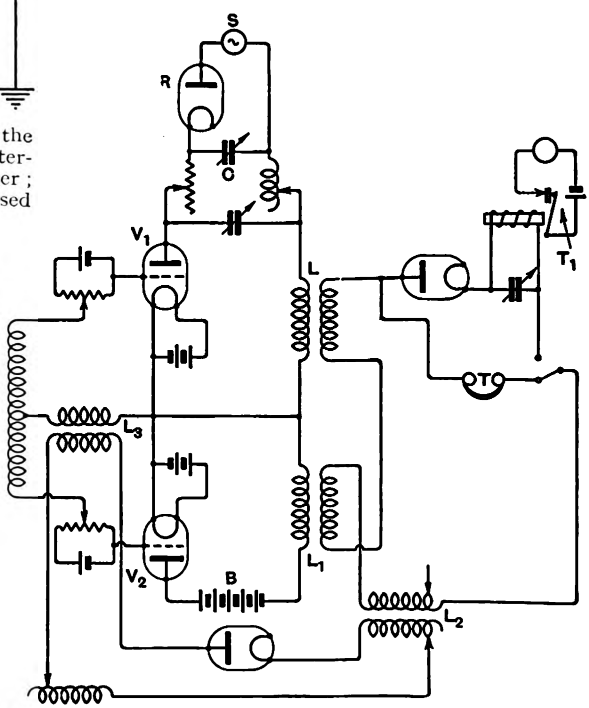
(*Application date, 8th September,* 1927. *No.* 299151.)

In order to prevent heavy sparking when keying high-power valves the grid circuit is made and



broken in a definite sequence. On breaking, the leak-resistance branch is opened first, and afterwards the branch containing a grid condenser; whilst in making, the condenser branch is closed





first, to dispose of any residual charge, and then the resistance branch.

As shown in the Figure, the three contacts of the key *K* open in the order 1, 2, 3. The spark which would normally occur on the opening of 1 is absorbed by the condenser *C*, which can still discharge through contacts 2 and 3. If any residual charge is left in the condenser *C* when contact 2 opens, it can still discharge through contact 3 which is broken last. On "making," contacts 3 and 2 close in that order, so that any condenser charge flows to earth. Lastly, contact 1 closes to connect the leak-resistance to earth, so that the valve oscillations recommence smoothly and at once. The distance *x*, *y* and *z*, in diminishing order, are adjusted by means of screws.

Patent issued to Siemens Bros. & Co., Ltd.

PREVENTING INTERFERENCE.

(*Application date, 25th June,* 1927. *No.* 297709.)

Relates to a method of eliminating atmospherics which depends upon the use of what is called a "fatigue" circuit in combination with a "constant" circuit. The two circuits are fed from a common input, but the outputs are opposed so that a sudden impulse which affects both the "fatigue" and constant circuits alike is balanced out, whereas a prolonged signal wears out the opposition of the "fatigue" circuit and so wins through to the telephones or recorder.

By a suitable initial setting of the two circuits the arrangement can be used to separate out a desired signal from an interfering signal of different frequency.

As shown in the Figure the incoming signals after suitable amplification are fed through an

intermediate circuit A comprising current-limiting devices a, a_1 to a circuit B fitted with full-wave rectifiers b, b_1. The rectified energy is then transferred to two thermionic amplifiers V_1, V_2 arranged in push-pull. The amplifier V_1 is fed with an adjustable supply of rectified high tension from a source S through a rectifier R, reservoir condenser C, and smoothing impedance. This forms the "fatigue" circuit because any prolonged signal applied to the grid of that valve will exhaust the H.T. supply, and so render the valve ineffective. The amplifier V_2 is supplied from a steady H.T. battery B. The output is reversed across the windings L, L_1, any resultant effect in the coil L_2 being back-coupled through a coil L_3 to the input circuit. The signals may operate a telegraphic relay T_1 or pass to a pair of telephones T.

Patent issued to E. G. Gage.

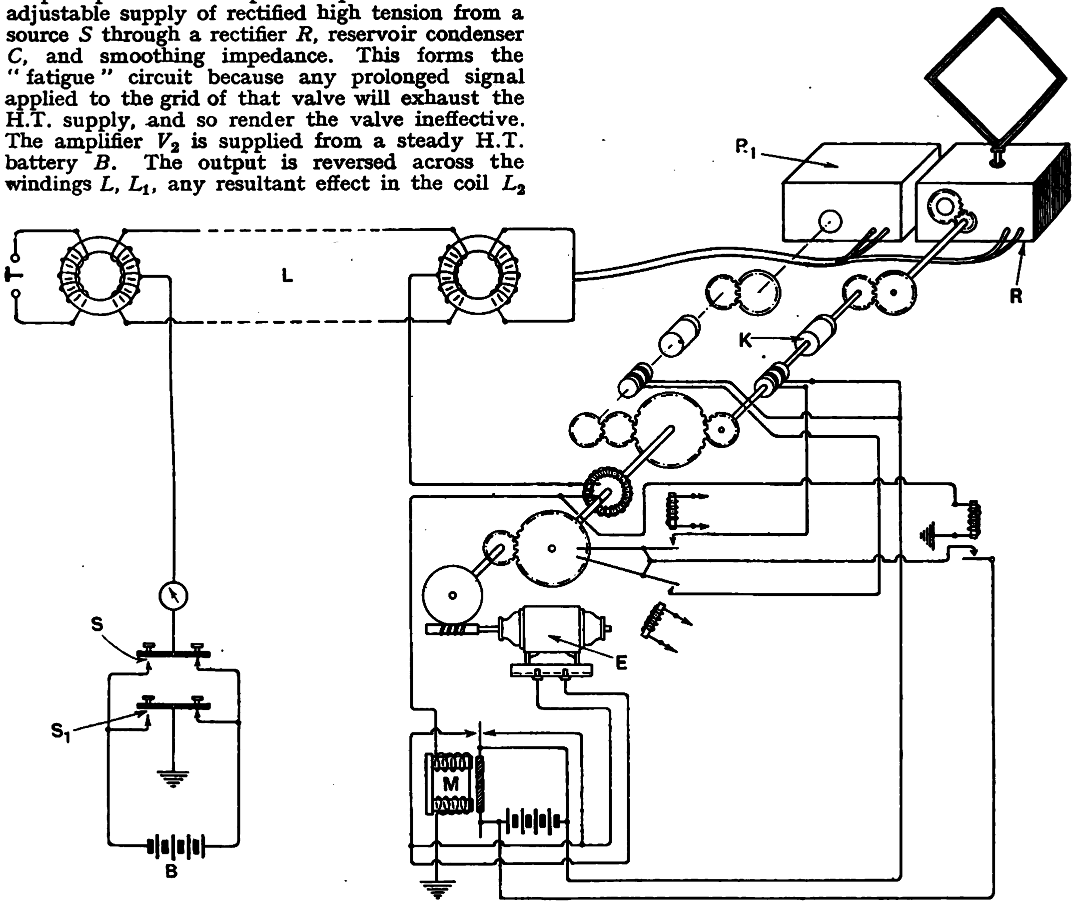
REMOTE CONTROL OF RECEPTION.

(*Convention date* (*Germany*), *22nd February*, 1927. *No.* 285835.)

The invention contemplates the installation of a wireless broadcast service designed primarily for the distribution of urgent news, or for stock-exchange quotations and similar information of business value. In such a case the service must be available at any moment of the day, and the message must be absolutely clear and dependable. To meet these requirements the receiving aerial should preferably be located some distance outside the town so as to be clear of serious sources of interference.

In order to give a business house efficient control of the distant receiver, without the necessity of employing a special operator at the distant point, tuning to any desired wavelength is effected through local switches, the current necessary to operate the distant relays being carried by the low-frequency speech line. According as the switch contact S or S_1 is closed, the positive or negative pole of the battery B is connected to line L, and a distant relay M is thrown to one side or other to reverse the direction of rotation of a motor E. This in turn controls the setting of the tuning-condenser of the receiver R through the chain of gearing shown. The gearing includes (1) a magnetic clutch K which is released when the local contact S or S_1 is raised (as the required message is heard), and also (2) means to prevent over-running of the gear and possible displacement of the final condenser setting. A duplicate receiver R_1 can be switched into circuit should a valve burn out.

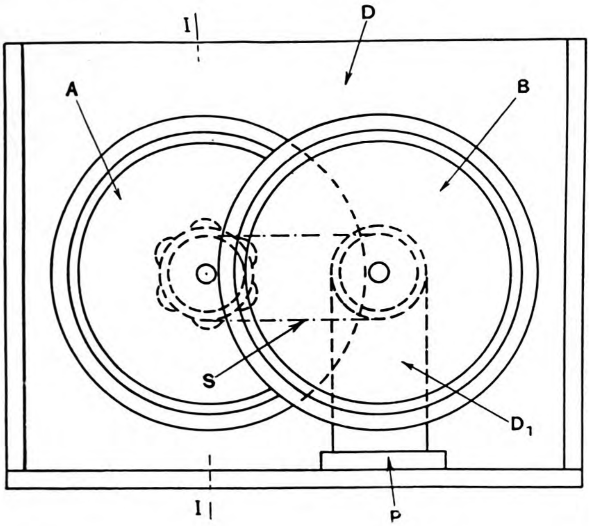
Patent issued to the C. Lorenz Co., Ltd.

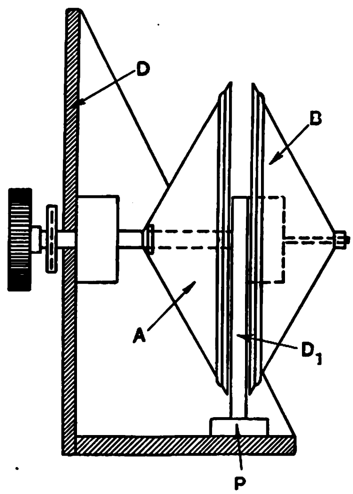


DUPLEX LOUD SPEAKERS.

(*Convention date* (*Germany*), 27*th January*, 1928. *No.* 300849.)

The capacity of a loud speaker to reproduce high and low notes depends to a large extent upon





the size of the resonating surfaces. In order to attain an equal overall response, covering a wide range of frequencies, two separate cone speakers A, B are used in combination, as shown. The diaphragm of the speaker A is mounted on a large resonant panel D of three-ply wood. It therefore tends to emphasise the lower notes. The diaphragm of the second speaker B is, by contrast, mounted on a rigid non-vibrating support D_1 secured at its lower end to a heavy base-plate P. It therefore reproduces at a higher pitch than the first. By mounting the two speakers so as to overlap, and by arranging the conical diaphragms face to face as shown, a correct balance between the high and low notes can be secured. At the same time, the resultant sounds appear to come from a single origin. A single control band S is used to adjust the air-gap in the magnetic drive of both speakers simultaneously.

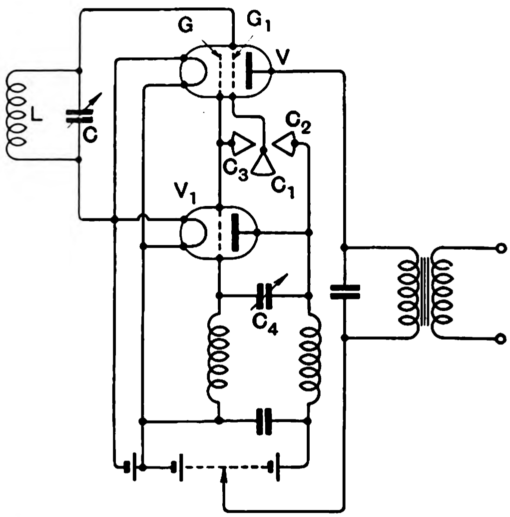
Patent issued to the Radiophon Co.

HETERODYNE RECEPTION.

(*Convention date* (*France*), 13th *July*, 1927. *No.* 293839.)

A two-fold heterodyne effect is secured from a four-electrode valve with the object of increasing or, under certain conditions reducing, the normal signal strength. The aerial input is applied from the tuned circuit L, C across the grid G_1 and filament of the tetrode V, and is combined in the plate circuit with oscillations of a slightly different frequency generated by the back-coupled triode V_1 and applied to the grid G.

A three-pole condenser C_1, C_2, C_3 couples the local oscillator V_1 to the grid G_1 of the tetrode V. As the plates C_2 and C_3 are across the condenser C_4 the momentary voltages at these points are in phase opposition. The two heterodyne effects therefore either reinforce or neutralise each other according as the plate C_1 overlaps the plate C_2 or C_3. If the signal wave-length is longer than the local oscillation, the two heterodynes add together in the plate circuit when the plate C_1 overlaps the plate C_2, whilst they neutralise each other if the coupling is between C_1 and C_3. On



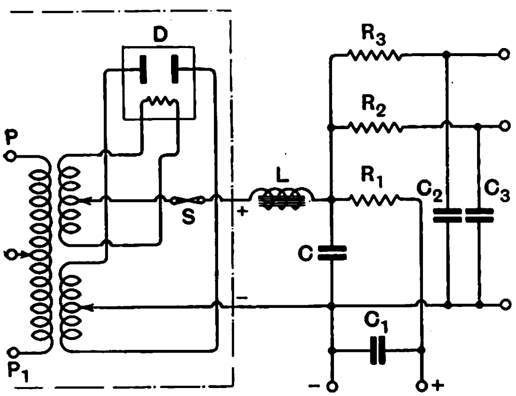
the other hand, if the incoming signal is shorter in wave-length than the local oscillations, these conditions will be reversed.

Patent issued to H. J. J. M. de R. de Bellescize.

MAINS SUPPLY UNITS.

(*Convention date* (*Germany*), *4th August,* 1926. *No.* 275624.)

The use of choking-coils in the smoothing circuit of a main-eliminator unit is necessarily costly



where the circuit is designed to pass the considerable output required for power amplification. Resistance-capacity networks have been used as an alternative, the smoothing action in this case increasing as the product of the resistance and capacity elements in circuit. The latter method has, however, the drawback of introducing a large voltage drop, which, particularly in the first stage, varies according to the current consumption of the later or power amplifying stages.

In order to overcome this defect, a separate resistance-capacity filter ciruict is provided, in parallel, for each stage of valve amplification, the separate filter units being individually designed according to the output and the degree of smoothing required. As shown, the input supply across the points P, P_1 is fed to a rectifier D, the output circuit of which comprises a safety-fuse S, choke L, and blocking condenser C. From here the first filtering-circuit, comprising a resistance of R_1 of 60,000 ohms and a condenser C_1 of 2 mfds, feeds the first high-frequency valve, which is most sensitive to supply fluctuations, but consumes least current. A second circuit, containing a resistance R_2 of 25,000 ohms and a condenser C_2 of 2 mfds., feeds the detector valve, whilst a resistance R_3 of only 300 ohms, shunted by a condenser C_3 of 4 mfds., supplies the power valve, where an adequate output is of more importance than efficient smoothing.

Patent issued to Siemens & Halske Akt.

Important Patent Decision.

Reserved judgment has now been given in the action in which the Lektophone Corporation of Jersey City, U.S.A., sued Messrs. S. G. Brown, Ltd., of Willesden, N.W., for the sale of " Mascot " loud speakers in infringement of the former's patent rights.

The Lektophone Corporation are legal owners of Patent No. 16602 issued in 1914 to Marcus Clarence Hopkins, which claims " A sound regenerating machine—in which a tympanum of at least nine inches in diameter is provided, freely exposed to the air in which the sounds are to be propagated, the tympanum having a central conical portion surrounded by an annular portion which is supported in a rigid manner at its periphery."

Plaintiffs alleged that the " Mascot " loud speaker as sold by Messrs. S. G. Brown fell within this claim, which by inference covers any loud speaker of the same general type, *i.e.*, in which a large disc or cone with clamped edges radiates directly into the surrounding air, *i.e.*, without the intervention of a horn.

Defendants denied infringement, and counterclaimed for the revocation of the patent in question on the grounds of lack of novelty and subject matter, and of insufficiency of description.

During the course of the hearing, expert evidence was given on both sides by various eminent authorities. Dr. Eccles, F.R.S., in particular occupied the witness box for the best part of five days, and answered approximately 2,500 questions.

The main issue centred around the point as to whether a sound-reproducing diaphragm invented in 1914 for use with a gramophone could reasonably be held to apply to the modern loud speaker as used in combination with thermionic valve amplifiers for broadcast reception.

Defendants' Counsel contended that the Hopkins patent extended only to machines of the stylus-driven type in which the driving power is small by comparison with that delivered from a multi-valve receiver.

In delivering his considered judgment, Mr. Justice Tomlin accepted this view. He pointed out that at the time of the Hopkins patent the use of sound reproducers was practically limited to gramophones and similar stylus-driven machines. The thermionic valve amplifier as used in modern Broadcast reception was then unknown. His Lordship went on to say that he had seen a number of loud speakers said to have been constructed under licences issued by the Plaintiffs—the owners of the Hopkins patent. Many of them seemed to him to bear little resemblance to the Hopkins diaphragm, but he was not concerned to say more on this point. In his view the Mascot loud speaker did not infringe the Hopkins patent, and he gave judgment for the Defendants (Messrs. S. G. Brown) accordingly on the issue of infringement.

The Defendants' counterclaim had not however been sustained. His Lordship found the Hopkins patent valid as applied to a stylus-driven machine. On this point judgment would accordingly be in favour of the Lektophone Corporation.

His Lordship divided the costs on the main issue, four-fifths to the Defendants, and one-fifth to the Plaintiffs. On the counterclaim costs followed the judgment.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. APRIL, 1929. No. 67.

Editorial.

On the Sound Waves Radiated from Loud-speaker Diaphragms.

THE problem of the nature of the sound waves in the neighbourhood of a piston or rigid diaphragm vibrating either in free space or in a baffle or wall of infinite extent appears to have been first studied by Lord Rayleigh. Most subsequent workers quote his classical "Theory of Sound," published in 1877, as the basis of their investigations. Interest in the subject has increased very much during recent years due to the advent of the loud speaker, and a number of researches have been published which enable one to form a fairly clear picture of the acoustic field in the neighbourhood of such a vibrating diaphragm. Although the results of these researches are well known to those more intimately associated with the scientific side of loud-speaker design and development, it is thought that a *résumé* of the results will be of interest to other readers, especially as they explain peculiarities which a critical listener may detect in the output of certain loud speakers.

In 1926 Erwin Meyer, of the German Government Telegraph Department, published the results of a large number of measurements of pressure and velocity in the sound waves from various types of loud speakers, including an exploration of the field in the neighbourhood of a large horn, the mouth of which may perhaps be regarded as equivalent to a vibrating piston. The results showed, as he pointed out, that with

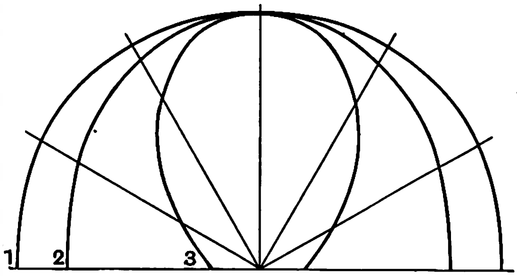

Fig. 1.

(1) $\frac{2R}{\lambda} = \frac{1}{4}$; (2) $\frac{2R}{\lambda} = \frac{1}{2}$; (3) $\frac{2R}{\lambda} = 1$;

$2R$ = *diameter of diaphragm*,
λ = *wavelength*.

increasing frequency the radiation became more directive, that is to say, the energy was concentrated into a narrower beam in front of the loud speaker and less of it was radiated sideways. In the same year Backhaus and Trendelenburg published the results of experiments made in the Siemens laboratories

in Berlin with Riegger's Blatthaller, the rectangular diaphragm of which, more than that of any other type of loud speaker, may be regarded as a rigid piston. They also gave a theoretical investigation of the acoustic field of such a piston diaphragm based on the velocity potential, a conception first introduced into hydrodynamics by Lagrange, but applied to this problem by Lord Rayleigh. The potential at any point due to any small element of the diaphragm is equal to the axial velocity of the diaphragm divided by the distance between the point and the element and multiplied by $1/2\pi$. The velocity to be taken is not that at the moment considered but at an earlier moment, the interval being the time required for the sound to travel from the diaphragm to the point. It is thus strictly analogous to the retarded potential of electrical theory. The pressure of the sound wave at any point is proportional to the rate at which the velocity potential at the point is changing. Backhaus and Trendelenburg established a formula for the intensity of the wave at various points along the axis, and showed that there were certain points at which the intensity was zero; the distances of these points from the diaphragm depends on the frequency. The elimination of the sound of a given frequency at such a point is due to interference between the waves arriving in different phases from different parts of the diaphragm. Complete elimination can only exist for a finite number of points; as the distance from the diaphragm increases the interference effects become less marked. To avoid any anomalous results due to this phenomenon, measurements of sound intensity should not be made too close to the loud speaker. In the Bell Telephone Laboratories the minimum distance is taken as $D^2f/4{,}500$ft., where D is the diameter of the diaphragm or piston in feet, and f is the frequency concerned. This working rule agrees with the results of Backhaus and Trendelenburg. Although they did not work out a formula for the intensity of radiation in various directions, they made a large number of careful measurements and plotted polar curves for various frequencies; these showed that as the frequency was increased the sound became more and more concentrated in a narrow axial beam. A person sitting towards the side, say, at an angle of 45 deg., will thus hear a different quality of sound from a person situated directly in front of the loud speaker, since the higher harmonics will be reduced more than the lower frequencies.

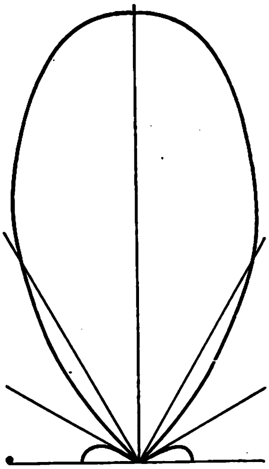

Fig. 2. $\frac{2R}{\lambda} = \frac{3}{2}$.

A very masterly analysis of the directive problem was published in 1927 by Stenzel who, after investigating the properties of a row of point sources—a problem somewhat analogous to that of the beam aerial—established formulæ for the radiation in any direction from rectangular and circular diaphragms. His calculated polar curves agree very well with the experimental results obtained by Backhaus and Trendelenburg. For a circular diaphragm of radius R in an infinite baffle he showed that the ratio of the intensity of the sound wave at an angle α to the axis to the intensity on the axis is given by $2\frac{J_1(z)}{z}$ where $z=2\pi\frac{R}{\lambda}\sin\alpha$, and $J_1(z)$ is the Bessel function of the first order, which may be expressed as a series, giving the result:—

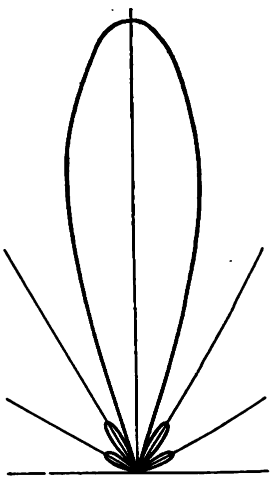

Fig. 3. $\frac{2R}{\lambda} = 3$

$$2\frac{J_1(z)}{z} = 1 - \frac{z^2}{2.4} + \frac{z^4}{2.4.4.6} - \frac{z^6}{2.4.4.6.6.8} + \dots$$

$$= 1 - \frac{(z/2)^2}{1.2} + \frac{(z/2)^4}{(1.2)(1.2.3)} - \frac{(z/2)^6}{(1.2.3)(1.2.3.4)} + \ldots$$

On the axis $\alpha = 0$ and therefore $z = 0$ and the series reduces to unity. Stenzel gives a curve showing the value of the series for various values of z. From the formula for z it can be seen that for a given diameter $2R$ of diaphragm the angle corresponding to a given value of z and therefore to a given reduction of intensity, is the smaller the shorter the wavelength. We reproduce the calculated curves for values of the diameter ranging from a quarter of the wavelength to five times the wavelength.

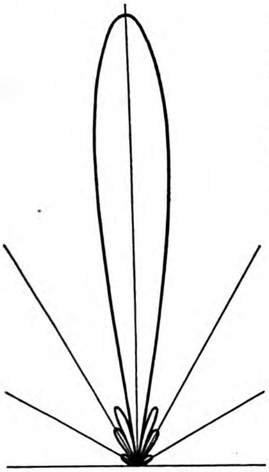

Fig. 4.
$\frac{2R}{\lambda} = 5$

Fig. 1 shows that the directive effect is negligible for wavelengths four times the diameter, but already quite pronounced for wavelengths equal to the diameter. Figs. 2, 3 and 4 show how the effect increases as the wavelength becomes a multiple of the diameter and also how small secondary maxima develop. Figs. 5 and 6 show the experimental results obtained by Backhaus and Trendelenburg with a giant Blatthaller with a pertinax membrane 53 cm. square; Fig. 5 was obtained with a frequency of 200 and Fig. 6 with a frequency of 4,500 cycles per second.

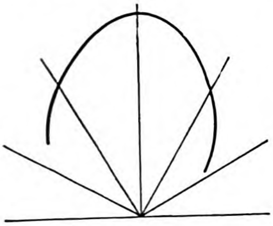

Fig. 5.
Diaphragm 53 *cm.* × 53 *cm.*, $f = 200$.

A general review of the subject has recently appeared in a series of articles by Trendelenburg in the *Zeitschrift für Hochfrequenz Technik*, and an article on Loud Speaker Measurements by Bostwick in the January issue of the *Bell System Technical Journal* contains some experimental polar curves taken at various frequencies, bringing out very clearly the concentration at high frequencies. Although the Blatthaller may approximate to the rigid piston, the ordinary centre-driven diaphragm does certainly not do so except at very low frequencies. Stenzel considers the problem of the diaphragm held rigidly at the edge and vibrating either at its fundamental or at one of its higher frequencies, and he indicates how approximate solutions may be obtained for the simplest cases, but such a problem is much more complicated than that of the rigid piston. The results of theory and experiment all tend to show that the large rigid piston type of diaphragm is unsuitable for the radiation of high quality music or speech, since the quality depends largely on the position of the listener. We give a bibliography of the subject for the sake of those who may wish to consult the articles to which we have referred.

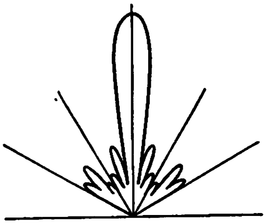

Fig. 6.
Diaphragm 53 *cm.* × 53 *cm.*, $f = 4{,}500$.

G. W. O. H.

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The Algebraic Representation of Triode Valve Characteristics.

By W. A. Barclay, M.A.

THE ordinary "lumped" characteristic of the triode valve is so well known as to require no explanation here. If $v_l = v_a + \mu v_g$, the relation between v_l and i_a is as depicted in Fig. 1, the symbols having their usual connotation. The curve as shown represents this relation for a given filament temperature. As v_l is increased, the current i_a approaches the "saturation" value I_s, which depends directly upon the filament temperature and thus upon the voltage at which the filament is being run. We may thus plot on the same diagram the several lumped characteristics of a valve pertaining to different filament voltages, and such families of curves are, of course familiar to readers of EXPERIMENTAL WIRELESS.

The problem of finding an algebraic equation which will conveniently symbolise the experimentally found lumped characteristic throughout its length is one of some difficulty. It is desirable that any such expression should be as simple as possible, containing few constants—not more than three or four—and that it should be of a form readily adapted for computation. Many expressions have from time to time been proposed which show the relationship for small values of v_l and i_a. These are usually of polynomial or exponential form, or sometimes a combination of the two, and are undoubtedly very convenient and easy to derive within a certain limited range of the variables. Thus we may write

$$i_a = A + Bv_l + Cv_l^2 + Dv_l^3 + \cdot \ . \ . \ .$$

in which the constants $A, B, C, D \ldots$ are found by experiment. Again, the index may be fractional, thus,

$$i_a = (A + Bv_l)^{3/2}$$

or more generally,

$$i_a = (A + Bv_l + Cv_l^2)^n$$

Further, we have the exponential type in which the independent variable v_l itself appears in the index, *e.g.*,

$$i_a = Ae^{Bv_l} + C$$

The constants in these formulæ are all readily determinable from the observed related values of v_l and i_a. If more observations are available than are necessary to determine the constants, the method of Alignment offers an expeditious means of utilising the data to obtain the best values, and is to be preferred to the method of Least Squares where time is lacking for the fuller enquiry. The writer hopes later to have an opportunity of dealing with the correlation of experimental data by the Alignment process.

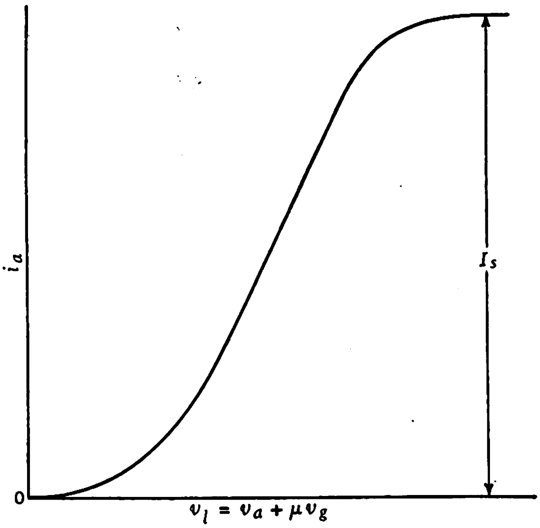


Fig. 1.—*Ordinary lumped characteristic at fixed filament voltage.*

The fundamental defect of such formulæ as have been cited is that beyond a certain limited range of values of v_l they cease to apply, so that in the region of saturation current they are quite unreliable, and, in fact, misleading. Now, the saturation

current value for a certain filament temperature is a well-defined quantity, constant for that temperature, and might almost be expected to appear in an algebraic relation between v_l and i_a. It seems to the writer that any form of algebraic representation which neglects I_s is *ipso facto* defective, while it is desirable at the same time that the equation sought for should be representative of the variables throughout the complete range of their variation.

The type of equation immediately suggested by the form of the characteristic of Fig. 1 is:

$$i_a = I_s(1 - A^{-v_l^B})$$

in which A and B are positive constants, and $A > 1$. As will be seen, this formula contains three constants, and satisfies at sight the extreme pairs of values,

$$v_l = 0,\ i_a = 0\ ;\ v_l = \infty,\ i_a = I_s.$$

Nevertheless, the actual determination of A and B from the substitution in the formula of other related values of v_l and i_a (or points on the curve) is a matter of some mathematical difficulty, as will readily appear if

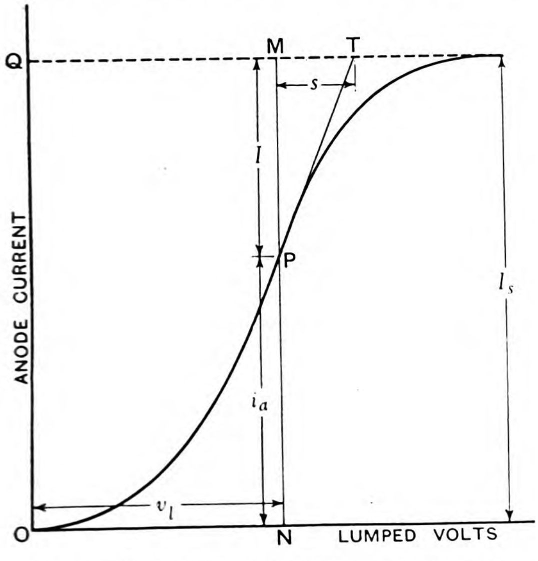


Fig. 2.—*Derivation of "s" from the lumped characteristic.*

trial be made. This disadvantage may, it is thought, have militated somewhat against the general use of this formula and others more complicated of similar type, and the writer believes that an account of a rapid means of estimating the constants of such formulæ may be found interesting and useful.

We shall take as our general form the equation

$$i_a = I_s\{1 - f(v_l)\} \quad \ldots \quad \ldots \quad (1)$$

where as usual I_s is the saturation value of current, and f is a function the constants of which are to be determined. In Fig. 2 let P be the point on the characteristic curve corresponding to the values v_l and i_a. Draw the horizontal line QM of ordinate I_s, and through P draw the vertical line MN to meet QM in M and the voltage axis in N. Draw also PT, the tangent to the curve at P, and let it meet the line QM at T. Then PN is, of course, i_a and if PM be taken as a new variable, I, say, we have

$$I = I_s - i_a$$

From equation (1), therefore,

$$I = I_s f(v_l)$$

$$\therefore \log I = \log I_s + \log f(v_l)$$

Differentiating. $\dfrac{1}{I}\cdot\dfrac{dI}{dv_l} = \dfrac{f'(v_l)}{f(v_l)}$

Now, $\dfrac{dI}{dv_l} = -\dfrac{di_a}{dv_l} = -\dfrac{PM}{MT}$

Also, $\dfrac{1}{I} = \dfrac{1}{PM}$

Therefore, $-\dfrac{1}{MT} = \dfrac{f'(v_l)}{f(v_l)}$

If, then, we represent by s the number of volts corresponding to the length of the subtangent MT for any given point P on the characteristic, we can write,

$$\frac{f'(v_l)}{f(v_l)} \times s = -1 \quad \ldots \quad \ldots \quad (2)$$

and from this relation the constants of the function f can, for the type of formula above considered, be readily determined.

For example, in the case of the equation

$$i_a = I_s(1 - A^{-v_l^B}) \quad \ldots \quad (3)$$

we have

$$f(v_l) = A^{-v_l^B}$$

Hence from equation (2) we have,

$$s\,.\,B\,.\log A\,.\,v_l^{B-1} = 1$$

or taking logarithms,

$$\log s + \log\{\log A^B\} + (B - 1).\log v_l = 0$$

This is a linear equation in $\log s$ and $\log v_l$. If, then, with abscissa $\log v_l$ and ordinate $\log s$ several corresponding values be taken, these should be found to lie along a straight line whose position and slope will afford a means of determining the quantities A and B. The degree of closeness with which the points as plotted approximate to a straight line indicates the correctness of the assumed type of formula. If the points show a systematic deviation from the linear form, *i.e.*, tend to dispose themselves along a regular curve, this will mean that the deviations are not due entirely to errors of observation, but that another type of assumed formula must be sought.

The practical utility of this method of deriving an algebraic equation for the lumped characteristic of a triode may be illustrated by an example in which the type of formula at first selected does not give the necessary linear relation from which the constants could be derived, so that it becomes necessary to modify it in a manner which will be described. The method of procedure is, however, perfectly general.

Examples of lumped characteristics extending over the full range of current values from zero to saturation are seldom met with, it being usually considered sufficient to take the characteristic over the normal working range only. It seemed appropriate, however, to illustrate the present method by a characteristic which had appeared in *Experimental Wireless*, and the writer therefore selected that shown on p. 28 of Vol. II. (Oct., 1924) for the French "Métal" valve as one of the few available showing the complete characteristics for various filament voltages. The four characteristics for filament voltages 3.2, 3.0, 2.8, and 2.6 are reproduced in Fig. 3, and will be referred to respectively as 1, 2, 3, and 4.

To begin with, it was decided tentatively to assume for these curves formulæ of the type

$$i_a = I_s(1 - A^{-v_l^B})$$

in which, of course, the constants I_s, A and B vary with the filament voltage. In particular, the values of I_s are read off straight away from the characteristics, being, in milliamps., 4.2, 3.1, 2.3, and 1.5.

In order to facilitate the use of common logarithms, the formula was re-written

$$i_a = I_s(1 - 10^{-av_l^b}) \quad .. \quad (4)$$

where a and b were to be found for each of the four curves. We may thus write

$$f(v_l) = 10^{-av_l^b}$$

$$\therefore \quad \log_{10} f(v_l) = -av_l^b$$

Whence by differentiation,

$$\frac{f'(v_l)}{f(v_l)} \times \log_{10} e = -abv_l^{b-1}$$

where e is the base of natural logarithms,

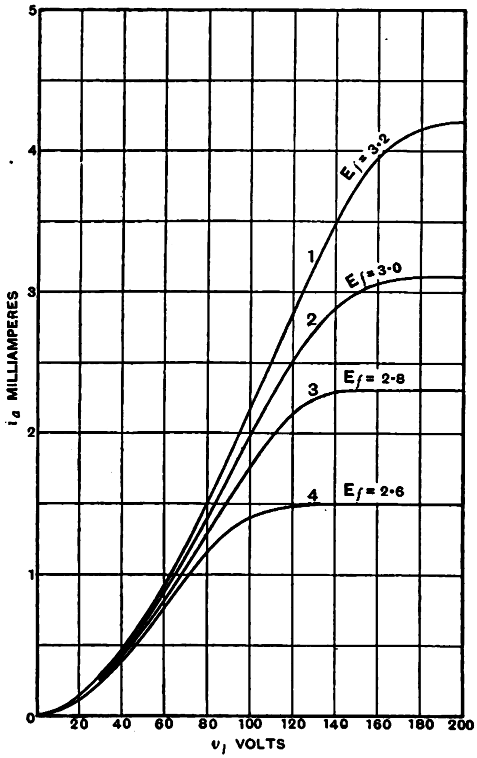


Fig. 3.—*Lumped characteristics of "Métal" for various filament voltages Ef.*

and $\log_{10} e = 0.434$. Therefore, by equation (2),

$$s\,.\,ab\,.\,v_l^{b-1} = 0.434.$$

Taking common logarithms,

$$\log s + \log ab + (b - 1).\log v_l = \log(0.434) \quad .. \quad (5)$$

which is a linear equation in $\log s$ and $\log v_l$.

Values of s for various values of v_l were

now obtained from the characteristics of Fig. 3 as explained above, and tabulated as under:

TABLE I.

v_l	Values of s.			
	1.	2.	3.	4.
40	196	150	118	70
60	125	92	70	37
80	89	58	41	19
100	65	38	22	10
120	40	24	11	6
140	28	15	—	—
160	18	8	—	—
180	10	—	—	—

The common logarithms of these quantities were also tabulated as shown below:

TABLE II.

log v_l	Values of log s.			
	1.	2.	3.	4.
1.60	2.29	2.18	2.07	1.85
1.78	2.10	1.96	1.85	1.57
1.90	1.95	1.76	1.61	1.28
2.00	1.81	1.58	1.34	1.00
2.08	1.60	1.38	1.04	0.78
2.15	1.45	1.18	—	—
2.20	1.26	0.90	—	—
2.26	1.00	—	—	—

From Table II values of log s for the four curves were plotted against values of log v_l, the result being shown in Fig. 4. It was immediately apparent that the loci of the various points could not be regarded as linear, and that the discrepancies must be due to an error in the assumed formula. The uniform concavity of the curves suggested, however, that the values of the abscissæ were unduly crowded at the right-hand side of the diagram, and that could these be spread out more the curves might assume the linear form. The reason for this constriction of the larger values of v_l seemed to lie in the logarithmic scale to which they were plotted, and it seemed, therefore, that if a scale of natural values of v_l were substituted as abscissæ the points might dispose themselves along straight lines as desired. That this, in fact, proved to be the case is shown by Fig. 5, which preserves the same vertical scale as Fig. 4, while using a natural instead of a logarithmic scale for abscissæ. In this diagram the linear distribution of the points is quite marked, and such deviations as occur may legitimately be ascribed to errors of observation and measurement.

The assumed formula (4) for our characteristics is thus shown to be incorrect, inasmuch as equation (5) no longer represents the straight lines of Fig. 5. We have now, therefore, to find a characteristic formula which, when used as described in conjunction with our "subtangent" method of finding constants, will yield a linear relation between log s and v_l. Such a formula is not hard to find by an inverse process of integration, the details of which need not be given here. The result may be expected to be slightly more complicated than our original formula, though, as will be seen later, this complication is more

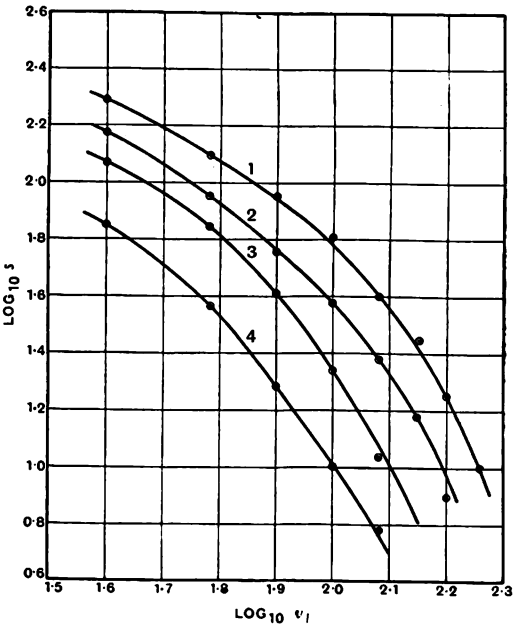


Fig. 4.—*Graph of data in Table II.*

apparent than real. In a form suitable for logarithmic computation, the desired formula may be written,

$$i_a = I_s\{1 - 10^{a(1-10^{bv_l})}\} \quad .. \quad (6)$$

where a and b are both positive constants.

This formula holds for the extreme values

$$v_l = 0,\ i_a = 0\ ;\ v_l = \infty,\ i_a = I_s$$

Also, since

$$f(v_l) = 10^{\,a(1-10^{bv_l})}$$

$$\log_{10} f(v_l) = a\,(1 - 10^{bv_l})$$

whence by differentiation,

$$\frac{f'(v_l)}{f(v_l)} \times (\log_{10} e)^2 = -\,ab \,.\, 10^{bv_l}$$

Therefore, by equation (2),

$$s \,.\, ab \,.\, 10^{bv_l} = 0.1886$$

and taking common logarithms,

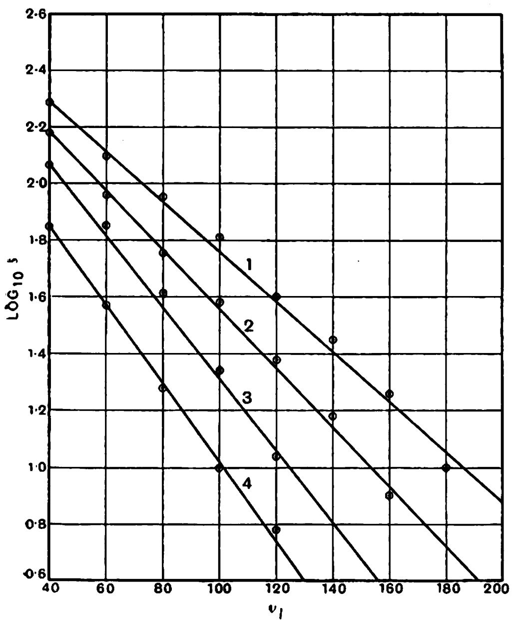


Fig. 5.—*Showing the effect of replotting Fig. 4, using linear instead of logarithmic abscissæ. The values of v_l are thus those of Table 1.*

$$\log s + bv_l + \log a + \log b + 0.724 = 0 \,..\, (7)$$

Equation (7) is the requisite linear relation between v_l and $\log s$ on the assumption of formula (6), and by means of it we can proceed to find the values of the constants a and b of equation (6) for the four straight lines of Fig. 5. Details of the calculation will here be given for No. 1 only. The best straight line having been drawn through the points for Characteristic No. 1 on Fig. 5, we note that the line passes through the values

$$(v_l = 40, \log s = 2.29) \text{ and } (v_l = 200, \log s = 0.88)$$

The equation of the line will therefore be

$$\frac{v_l - 40}{200 - 40} = \frac{\log s - 2.29}{0.88 - 2.29}$$

i.e., $\log s + 0.0088\, v_l - 2.66 = 0$ .. (8)

Comparing this with equation (7) we have immediately,

$$b = 0.0088$$

and $\log a + \log b + 0.724 = -\,2.66$

Therefore, $\log a = \bar{2}.68$

and $a = 0.048$

Similar calculations having been effected for the constants of the other three characteristics, we may summarise the results as follows :

TABLE III.

	No. 1.	No. 2.	No. 3.	No. 4.
I_s	4.2	3.1	2.3	1.5
a	0.048	0.046	0.041	0.055
b	0.0088	0.0104	0.0126	0.0139

From this table it is evident that a remains approximately constant for the changes of filament temperature shown, maintaining an average value of about 0.048. On the other hand, b varies with the voltage applied to the filament. If E_f denote this voltage, we may write approximately

$$b = 0.0360 - 0.0085\, E_f.$$

It must, however, be remembered that these expressions for a and b hold only for the extremely limited range of filament voltages given, viz., from 3.2 to 2.6 volts, and that outside this range they may well cease to be applicable. Further numerical data in order to trace the variation of a and b over wider ranges of filament temperture would be interesting and useful.

The simplicity of the application of formula (6) to the direct computation of current values deserves more than passing mention. By means of a table of common antilogarithms, the actual calculation from the formula becomes a matter of extreme

facility. Since, if $10^x = y$, $y = \text{antilog}\, x$ we may write formula (6) as follows:

$$i_a = I_s\{1 - \text{antilog}[a(1 - \text{antilog}\, bv_l)]\} \quad (9)$$

or,

$$i_a = I_s\{1 - \text{antilog}\, ap\}$$

where

$$p = (1 - \text{antilog}\, bv_l)$$

The convenience of the antilogarithmic function for the rapid evaluation of i_a will readily be appreciated. One example will suffice. Let us recompute values of i_a for the characteristic 1, using the values of a and b already obtained. We have,

$$i_a = 4.2\,(1 - \text{antilog}\, 0.048\, p)$$

where

$$p = (1 - \text{antilog}\, 0.0088\, v_l)$$

Then the work may be arranged as in Table IV in which, for purposes of comparison, has been included a column of values of i_a as read off direct from the characteristic of Fig. 3.

It will be observed that there is a fair measure of agreement between the observed and computed values of i_a. The writer might here point out that the calculations made in this article may all be considerably simplified by the method of Alignment, and that it is a simple matter to design charts which will effect at sight the various computations of Table IV. To this subject he may, perhaps, return.

Meanwhile, his present purpose is to direct attention to a formula which, it is believed, represents the lumped characteristic with considerable accuracy, and is, moreover, quite simple in use. It may be added that the utility of formula (6) is not confined to lumped characteristics, but may be employed to represent the ordinary triode valve characteristics with variable grid and anode voltages.

TABLE IV.

DETAILS OF THE CALCULATION OF i_a FROM EQUATION (9).

v_l	$.0088\, v_l$	antilog $.0088\, v_l$	p.	$.048\, p$.	antilog $.048\, p$.	1 — antilog $.048\, p$.	i_a (computed)	i_a (actual)
40	0.352	2.25	− 1.25	$\bar{1}.940$	0.87	0.13	0.55	**0.47**
60	0.528	3.37	− 2.37	$\bar{1}.886$	0.77	0.23	0.97	**0.92**
80	0.704	5.06	− 4.06	$\bar{1}.805$	0.64	0.36	1.51	**1.51**
100	0.880	7.59	− 6.59	$\bar{1}.684$	0.48	0.52	2.18	**2.17**
120	1.056	11.38	−10.38	$\bar{1}.502$	0.32	0.68	2.86	**2.83**
140	1.232	17.06	−16.06	$\bar{1}.229$	0.17	0.83	3.49	**3.48**
160	1.408	25.59	−24.59	$\bar{2}.820$	0.07	0.93	3.91	**3.94**
180	1.584	38.37	−37.37	$\bar{2}.206$	0.02	0.98	4.12	**4.15**
200	1.760	57.54	−56.54	$\bar{3}.286$	0.00	1.00	4.20	**4.20**

Book Review.

MEHRFACHRÖHRENEMPFÄNGER (Multiple - valve Receivers). By Manfred von Ardenne. 71 pp., with 67 Figures. Rothgiesser and Diesing, Berlin. 1.70 Marks.

This is really a fifth edition of the author's "Home Construction of Receivers with Multiple Valves," but in view of the extensive revision and additions it has been decided to alter the title and regard this as a first edition of a new work. The author has been closely associated with Loewe in the development of the multiple valve and this booklet discusses all the possible applications of this type of valve either alone or in conjunction with other types for various classes of receivers. One section is devoted to a short-wave receiver with a screen-grid valve and a multiple valve whilst another deals with a portable receiver with three high-frequency multiple valves. The book can be thoroughly recommended to those who have the necessary acquaintance with the language and are interested in the special type of valve with which the book deals.

G. W. O. H.

The Super-Position of Circular Motions.

By T. S. Rangachari, M.A., Assoc.I.R.E.

(Indian Institute of Science, Bangalore, India.)

SYNOPSIS.—By simple analysis the equations for the patterns arising from the simultaneous super-position on a particle, of two circular motions whose frequency ratio may be integral or fractional, are derived. The patterns are plotted with the help of these equations for various ratios of frequencies these being verified by actual observations on a cathode ray oscillograph.

The varying velocity of the particle along the pattern is examined and the advantages in the comparison of frequencies resulting therefrom are explained.

An investigation into the relation between the size of the loops of the pattern and the ratio of the amplitudes of the two impressed circular motions leads to the very interesting result that the loops just collapse into spots when the ratio of amplitudes is equal to the reciprocal of the ratio of frequencies.

IN the comparison of frequencies, the use of Lissajous figures is well known. These figures are produced by the super-position of two simple harmonic motions at right angles to each other and they have been plotted for various ratios of frequencies and given in text-books for ready reference. (See, for example, Lord Rayleigh's "Theory of Sound," Vol I, Chap. II.) The greater advantages of the use of the looped patterns obtained by the super-position of two circular motions imparted to the cathode ray spot on the screen of a cathode ray oscillograph for the comparison of radio frequencies were first pointed out by D. W. Dye (*Proc. Phys. Soc.* 1925, 37, 158), who also suggested several practical methods for producing them. A modification of Dye's method was described by the author in the pages of this journal (May, 1928, p. 264). In view of the importance of Dye's method it would be useful to examine in more detail the nature of the patterns arising from the super-position of circular motions both when the ratio of frequencies is integral and also fractional so that the patterns may be plotted for ready reference as has been done in the case of the Lissajous figures. Incidentally the remarkable properties of these patterns and the special advantages arising therefrom may be elucidated.

The nature of the patterns is here investigated for the two cases where the two circular motions influencing the cathode ray spot are

(1) in the same direction,
(2) in opposite directions.

Under each of the above two divisions the following points are examined.

(*a*) The shape of the pattern when the ratio of frequencies is integral.

(*b*) The velocity of the cathode ray spot along the pattern and the advantages resulting therefrom.

(*c*) The dependence of the size of the loops of the pattern on the ratio of the amplitudes of the impressed potentials.

(*d*) The shape of the pattern when the ratio of frequencies is fractional.

(1) Case when the two Circular Motions are in the same Direction.

(*a*) *Equation for the shape of the pattern when the ratio of frequencies is integral.*

The equation for the path of the cathode ray spot which we may consider as a particle, can be derived from the fact that its position at any instant is determined by the combination of two vectors representing the two circular motions due to the applied potentials whose frequencies are to be compared.

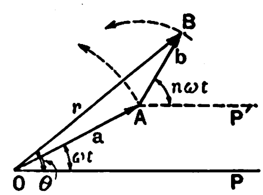
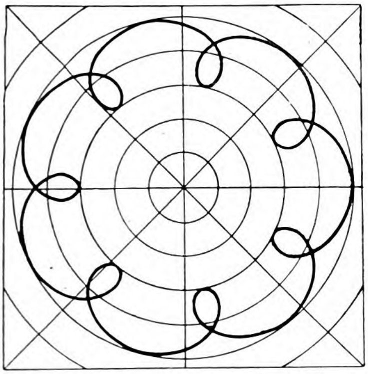


Fig. 1.

Referring to Fig. 1 let O be the origin and OP the reference vector for polar co-ordinates. Let OA be an instantaneous position of the vector representing the circular motion at the lower frequency. Let AB be the position at the same instant, of the vector representing the circular motion at the higher frequency. Let the ratio of frequencies be

$n:1$. If the vector OA makes an angle ωt with OP then the vector AB makes an angle $n\omega t$ with OP, assuming that the two vectors are in phase along OP and that ω is the angular velocity of the low-frequency vector. It is evident that the instantaneous position of the cathode ray spot due to both the



$n = 8$. a=4 UNITS. b= 1 UNIT

Fig. 2.

vectors is the point B, and the vector OB is the resultant whose length r gives the distance of the spot at that instant from the origin and the angle θ which it makes with OP gives its orientation. r and θ completely define the position of the spot at time t when the vector OA is at an angle ωt. Let us evaluate r and θ in terms of ωt, a and b, where a and b are the radii of the lower and higher frequency circular motions respectively. It is easily seen that

$$OB = r = \{(a \cos \omega t + b \cos n\omega t)^2 + (a \sin \omega t + b \sin n\omega t)^2\}^{\frac{1}{2}}$$

or $$r = [a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t]^{\frac{1}{2}} \quad \ldots \quad (1)$$

$$\tan \theta = \frac{a \sin \omega t + b \sin n\omega t}{a \cos \omega t + b \cos n\omega t} \quad \ldots \quad \ldots \quad (2)$$

With the help of the equations (1) and (2) the path of the cathode ray spot, *i.e.*, the pattern can be plotted by varying ωt from 0 deg. to 360 deg. Equation (1) shows that the minimum value of r is $a - b$ and the maximum value $a + b$. As ωt varies from 0 deg. to 360 deg. the radius vector r of the pattern assumes all values between $a - b$ and $a + b$.

Before plotting the pattern, however, it is useful to find out the values of θ for maximum and minimum values of r. The condition for this is $\frac{dr}{d\theta} = 0$.

Now

$$\frac{dr}{d\theta} = \frac{dr}{dt} \cdot \frac{dt}{d\theta}.$$

From equation (1)

$$\frac{dr}{dt} = \frac{-ab\omega(n-1) \sin \overline{n-1}\,\omega t}{[a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t]^{\frac{1}{2}}} \quad \ldots \quad (3)$$

From equation (2)

$$\frac{dt}{d\theta} = \frac{a^2+b^2+2ab \cos \overline{n-1}\,\omega t}{\omega\{a^2+nb^2+(n+1)ab \cos \overline{n-1}\,\omega t\}} \quad \ldots \quad (4)$$

$$\therefore \frac{dr}{d\theta} = \frac{-\{a^2+b^2+2ab \cos \overline{n-1}\,\omega t\}^{\frac{1}{2}}\, ab(n-1) \sin \overline{n-1}\,\omega t}{a^2+nb^2+\overline{(n+1)}ab \cos \overline{n-1}\,\omega t}$$

If $\frac{dr}{d\theta} = 0$, then $(n-1)\,\omega t = 0$ or $n'\pi$ where n' is any integral number.

$$\therefore \quad \omega t = \frac{n'\pi}{n-1} \text{ or } 0.$$

Thus the maximum and minimum values of r occur when

$$\omega t = \frac{n'\pi}{n-1} \text{ or } 0.$$

Now let us find out what relation θ bears to ωt at the maximum and minimum positions of r.

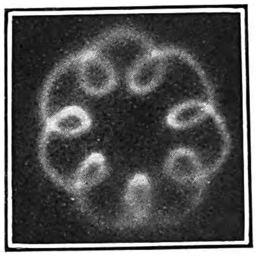


Fig. 3.

We have

$$\tan \theta = \frac{a \sin \omega t + b \sin n\omega t}{a \cos \omega t + b \cos n\omega t}$$

$$= \frac{a \sin \omega t + b \sin (\overline{n-1}\,\omega t + \omega t)}{a \cos \omega t + b \cos (\overline{n-1}\,\omega t + \omega t)}$$

$$= \frac{a \sin \omega t + b \sin \overline{n-1}\,\omega t \cos \omega t + b \cos \overline{n-1}\,\omega t \sin \omega t}{a \cos \omega t + b \cos \overline{n-1}\,\omega t \cos \omega t - b \sin \overline{n-1}\,\omega t \sin \omega t}.$$

Since $(n-1)\,\omega t = 0$ or $n'\pi$ when $\frac{dr}{d\theta} = 0$, the above equation reduces to

$$\tan \theta = \tan \omega t$$

or $$\theta = \omega t.$$

Thus the maximum and minimum values of r occur at $\theta = \frac{n'\pi}{n-1}$ or 0.

For example, let the ratio n of the two frequencies be 8. Then it is easily seen that

(i) maximum values of r occur at $\theta = 0°$, $51°\frac{3}{7}$, $102°\frac{6}{7}$, $154°\frac{2}{7}$, $205°\frac{5}{7}$, $257°\frac{1}{7}$, and $308°\frac{4}{7}$.

(ii) minimum values of r occur at $\theta = 25°\frac{5}{7}$, $77°\frac{1}{7}$, $128°\frac{4}{7}$, $180°$, $231°\frac{3}{7}$, $282°\frac{6}{7}$ and $334°\frac{2}{7}$. Since these values occur at regular intervals it can be inferred that the pattern is a symmetrical figure. Hence if the values of r and θ are calculated for values of ωt varying from 0° to $51°\frac{3}{7}$ with the help of equations (1) and (2) the whole pattern can be plotted since the same values of r repeat with a period of $51°\frac{3}{7}$ in this case.

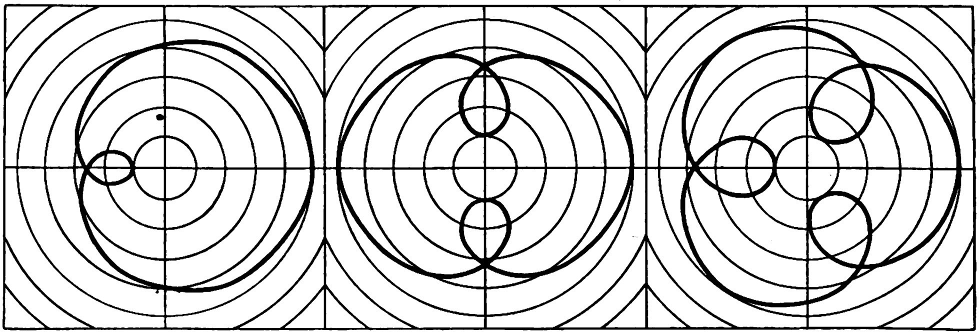
Table I shows the values of r and θ thus calculated for $n = 8$, $a = 4''$ and $b = 1''$. Fig. 2 shows the pattern plotted. Fig. 3 shows a photograph of the pattern observed on the oscillograph screen when $n = 8$.

In Fig. 4 the shapes of the patterns for various ratios, which are plotted in this manner, are shown. It is observed that the patterns have loops inside, their number being $(n - 1)$. Conversely, when the loops are inside, the number of loops plus one gives the ratio of the two frequencies superimposed. Thus the determination of frequency is extremely simple when one of them is known, in that it involves only a counting of the number of loops. This is in contrast with the extreme complexity of the Lissajous patterns for high ratios.

(b) *The velocity of the cathode ray spots along the pattern.*

In Fig. 5 let $ABCDEF$ represent one loop of the pattern. Considering a small element ds of the pattern we write the equation

$$(ds)^2 = (dr)^2 + (r d\theta)^2.$$



$n = 2$ $n = 3$ $n = 4$

Fig. 4.

TABLE I.

ωt in degrees.	r in inches.	θ in degrees.						
0°	5.000	0°	$51°\frac{3}{7}$	$102°\frac{6}{7}$	$154°\frac{2}{7}$	$205°\frac{5}{7}$	$257°\frac{1}{7}$	$308°\frac{4}{7}$
5°	4.853	11° 47′	63° 13′	114° 39′	166° 5′	217° 31′	268° 57′	320° 23′
10°	4.443	22° 13′	73° 39′	125° 5′	176° 31′	227° 57′	279° 23′	330° 49′
12° 4′	**4.218**	**25° 43′**	77° 8′	128° 34′	180°	231° 26′	282° 52′	334° 18′
15°	3.864	29° 25′	80° 51′	132° 17′	183° 43′	235° 9′	286° 35′	338° 1′
20°	3.297	31° 14′	82° 40′	134° 6′	185° 32′	236° 58′	288° 24′	339° 50′
25°$\frac{5}{7}$	**3.000**	**25° 42′**	77° 8′	128° 34′	180°	231° 26′	282° 52′	334° 18′
30°	3.271	20° 56′	72° 22′	123° 48′	175° 14′	226° 40′	278° 6′	329° 32′
35°	3.690	20° 46′	72° 12′	123° 38′	175° 4′	226° 30′	277° 56′	329° 22′
39° 23′	**4.218**	**25° 42′**	77° 8′	128° 34′	180°	231° 26′	282° 52′	334° 18′
45°	4.760	36° 27′	87° 53′	139° 19′	190° 45′	242° 11′	293° 37′	345° 3′
$51°\frac{3}{7}$	5.000	$51°\frac{3}{7}$	$102°\frac{6}{7}$	$154°\frac{2}{7}$	$205°\frac{5}{7}$	$257°\frac{1}{7}$	$308°\frac{4}{7}$	360°

Since s, r, and θ are functions of time we may write

$$\frac{ds}{dt}=\left\{\left(\frac{dr}{dt}\right)^2+r^2\left(\frac{d\theta}{dt}\right)^2\right\}^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (5)$$

Equation (5) gives the velocity of the cathode ray spot along the pattern. Let us evaluate it.

From equation (3)

$$\left(\frac{dr}{dt}\right)^2=\frac{\omega^2 a^2 b^2 (n-1)^2 \sin^2 \overline{n-1}\,\omega t}{a^2+b^2+2ab\cos \overline{n-1}\,\omega t}.$$

From equation (4),

$$r^2\left(\frac{d\theta}{dt}\right)^2$$

$$=\frac{\omega^2\{a^2+nb^2+(n+1)ab\cos \overline{n-1}\,\omega t\}^2}{a^2+b^2+2ab\cos \overline{n-1}\,\omega t}$$

$$\therefore \left(\frac{ds}{dt}\right)^2$$

$$=\frac{\omega^2[\{a^2+nb^2+(n+1)\,ab\cos \overline{n-1}\,\omega t\}^2+a^2b^2(n-1)^2\sin^2 \overline{n-1}\,\omega t]}{a^2+b^2+2ab\cos \overline{n-1}\,\omega t}$$

or

$$\frac{ds}{dt}=\omega\{a^2+n^2b^2+2nab\cos \overline{n-1}\,\omega t\}^{\frac{1}{2}} \quad \ldots \quad (6)$$

Equation (6) gives the velocity of the spot and can be calculated for various values of ωt or θ. In Fig. 6 is plotted the velocity of the spot for values of ωt from 0° to 51°$\frac{3}{7}$, *i.e.*, for one loop, assuming $n = 8$, $a = 4''$, $b = 1''$ and $\omega = 2\pi \times 3{,}000$.

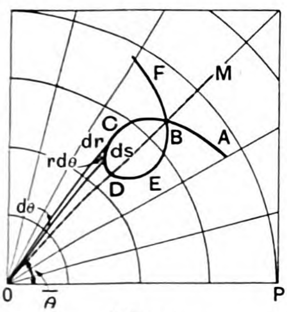


Fig. 5.

It is seen that the velocity is a maximum when r is maximum and minimum when r is minimum so that while the spot traces the loop, it has first a retarded motion till it reaches the minimum point of the loop, after which it has an accelerated motion. It is also seen that the velocity is symmetrical with respect to the radius vector passing through the minimum point of the loop. This is to be expected, for since the pattern is symmetrical there is no reason why the speed also should not be symmetrical. The advantage of this varying speed is that the loop is brighter than the other portions of the pattern. This contrast is intensified when the loop is reduced smaller and smalller by diminishing the amplitude of the higher frequency motion so that when it is reduced to a spot, the spot is the brightest portion of the pattern. When the ratio of frequencies is very high, of the order of 20, this property

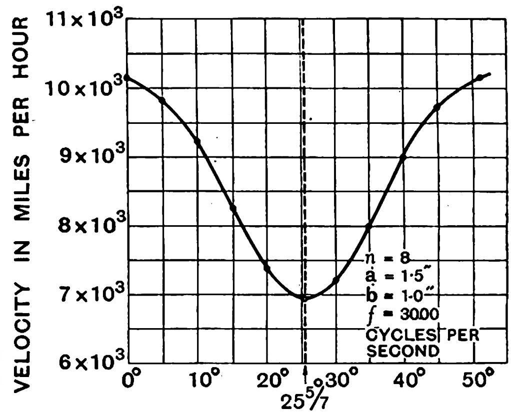


Fig. 6.

is of very great advantage since the pattern then consists of a number of circularly arranged bright spots connected by faint curves. By a mere counting of the number of the spots the ratio of frequencies is determined. On the other hand, if the whole of the pattern is equally bright, then the counting may not be so easy. Fig. 7 shows a photograph of the pattern when $n = 7$ and the loops are reduced to spots. The difference in brightness has not come out clearly in the photograph, but on the oscillograph screen it is well observed.

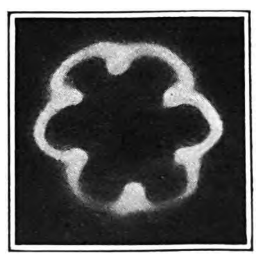
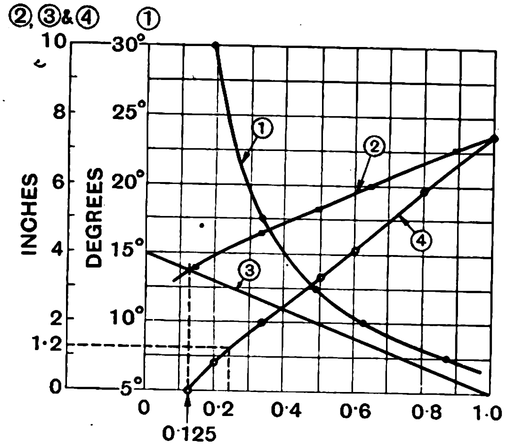


Fig. 7.

(c) *The size of the loops in relation to the ratio of amplitudes.*

It is interesting to enquire what relation the size of the loops bears to the ratio of the amplitudes of the two circular motions. For, it has already been pointed out that the

reduction of the loops to bright spots is brought about by sufficiently diminishing the potential due to the higher frequency while keeping that due to the lower frequency constant.



$\frac{b}{a}$

Fig. 8.

Referring again to Fig. 5 let *ODBM* be the vector passing through the minimum point *D* of the loop and consequently through the intersection point *B*. Let us take the length *DB* as a measure of the size of the loop.

Then

$$DB = OB - OD.$$

Now let us consider the length *OB*.

From equation (1)

$$OB = \{a^2 + b^2 + 2ab \cos \overline{n - 1}\, \omega t_1\}^{\frac{1}{2}} \ldots (7)$$

where ωt_1 is the angle of the low frequency vector pertaining to the point *B*. Since our object is to determine how *OB* varies with $\frac{b}{a}$, we should first find out how ωt_1 in equation (7) depends upon $\frac{b}{a}$. Since the vector *ODB* passes through the minimum point *D* as well as the intersection point *B*, it is obvious there should be three values of ωt which give the same value of $\bar{\theta}$, where $\bar{\theta}$ is the angle *BOP* in Fig. 5. One of them must be equal to $\bar{\theta}$, which is the condition for r to be minimum as already shown. Let the other two be denoted by ωt_1 and ωt_2. Since r, *i.e.* *OB*, is the same both for ωt_1 and ωt_2, these must be connected by the relation

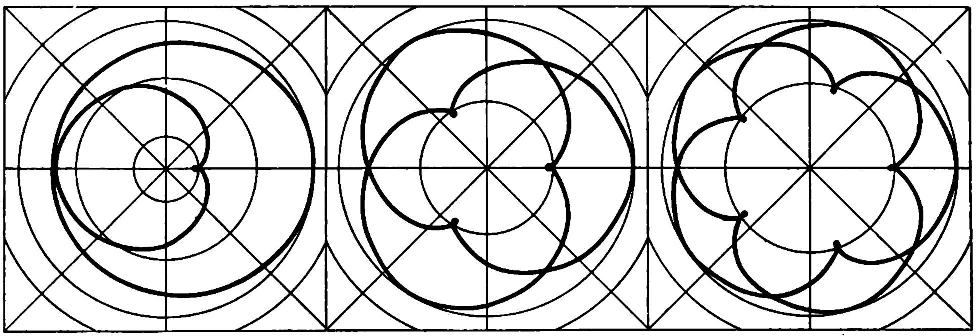
$$\omega(t_1 + t_2) = 2\pi$$

so that

$$\cos \overline{n - 1}\, \omega t_1 = \cos \overline{n - 1}\, \omega t_2.$$

Hence it is sufficient if we consider one value, viz.: ωt_1.

Let us now examine how the value of ωt_1 varies with the ratio $\frac{b}{a}$, keeping n constant.



$n = \frac{3}{2}$ $\frac{b}{a} = \frac{2}{3}$ $n = \frac{5}{2}$ $\frac{b}{a} = \frac{2}{5}$ $n = \frac{7}{2}$ $\frac{b}{a} = \frac{2}{7}$

Fig. 9.

We may now write equation (2) as follows:

$$\frac{\sin \omega t_1 + \frac{b}{a} \sin n\omega t_1}{\cos \omega t_1 + \frac{b}{a} \cos n\omega t_1} = \tan \bar{\theta}$$

$= \text{a constant } k$, since n is constant.

Or $\frac{b}{a} = \frac{\sin \omega t_1 - k \cos \omega t_1}{k \cos n\omega t_1 - \sin n\omega t_1}$.

Let $n = 8$, then $k = \tan \frac{\pi}{n - 1}$

$$= \tan \frac{\pi}{7} = 0.4813.$$

$$\therefore \frac{b}{a} = \frac{\sin \omega t_1 - 0.4813 \cos \omega t_1}{0.4813 \cos 8\,\omega t_1 - \sin 8\omega t_1} \quad .. (8)$$

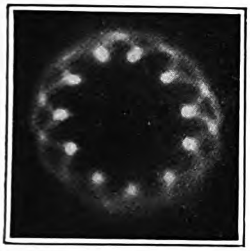


Fig. 10.

Equation (8) which gives the relation between ωt_1 and $\frac{b}{a}$ when $n = 8$, is plotted in Fig. 8 curve 1, for values of $\frac{b}{a}$ from zero to unity.

Now from equation (7),

$$OB = a\left\{1 + \left(\frac{b}{a}\right)^2 + 2\left(\frac{b}{a}\right) \cos \overline{n - 1}\, \omega t_1\right\}^{\frac{1}{2}} \quad .. (9)$$

Curve 2 in Fig. 8 is plotted with the help of equation (9) and curve 1 of the same figure. It shows how OB varies when $\frac{b}{a}$ varies from zero to unity assuming $a = 4''$.

Let us consider the length OD.

$OD = a - b$ since D is a minimum point for r.

Or $\qquad OD = a\left(1 - \frac{b}{a}\right)$.

Curve 3 of Fig. 8 shows the variation of OD with $\frac{b}{a}$ when $a = 4''$.

From curves 2 and 3 of Fig. 8, curve 4 in the same figure is plotted from the relation

$$DB = OB - OD.$$

Hence this curve represents how the size of the loop varies for values of $\frac{b}{a}$ from zero to unity. Two important observations must be made from this curve.

(1) For $\frac{b}{a} = 0.25$ the size of the loop is $1.2''$ if $a = 4''$. Referring to Table I, which is calculated for these same constants, it is observed that $OB = 4.218''$ and $OD = 3''$. Therefore the size of the loop is $4.218'' - 3'' = 1.218''$, which agrees with the above

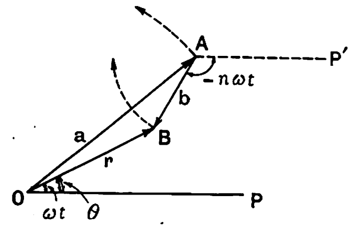
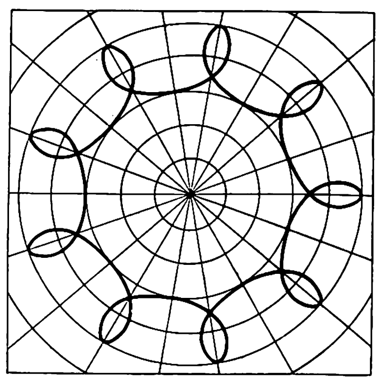


Fig. 11.

value. This verifies the correctness of curve 4 in Fig. 8.

(2) For $\frac{b}{a} < 0.125$ the size of the loop is zero. This is a very interesting observation. It leads to the inference that even when the cathode ray spot is an ideal point so that its trace on the screen is an ideally thin line, there is a minimum ratio of the amplitudes of the two circular motions below which the loops collapse into spots. This minimum ratio of amplitudes is given by the equation



n = 8. a = 4 UNITS. b = 1 UNIT.

Fig. 12.

$\frac{b}{a} = \frac{1}{n}$ where n is, as before, the ratio of frequencies.

(d) The form of the pattern when the ratio of frequencies is fractional.

The case when n is fractional is important,

for, in the comparison of two frequencies, if their ratio is integral there is a tendency for the sources to interlock, "ziehen." If n is made fractional this effect is not present. In practice the only important case is when $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc.

The equations 1 and 2 hold good even when n is fractional. The same solution holds good for the determination of the maximum and minimum values of r. These occur, as before, when $\theta = \dfrac{n'\pi}{n-1}$ or 0.

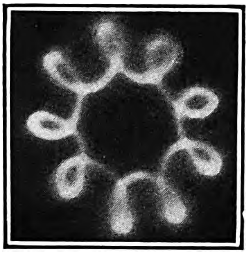


Fig. 13.

But when n is a fraction such as $\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., the nature of the expression

$$r = \{a^2 + b^2 + 2ab \cos \overline{n-1}\,\omega t\}^{\frac{1}{2}}$$

suggests that for the same value of θ given by $\theta = \omega t = \dfrac{n'\pi}{n-1}$ or 0, r is both a maximum and a minimum. This can be shown as follows.

When n is integral the values of θ for maximum and minimum values of r repeat, *i.e.*, the pattern is re-entrant when ωt completes a cycle of 360 deg. This can be made clear by an example. Suppose $n = 5$. Then the values of θ for maximum and minimum values of r occur as shown in Table II.

Two things are to be observed in this table. One is the angles connected by lines in the table are the same in space. The other is that the values of the radius vector r corresponding to these connected angles are either both maximum or both minimum.

TABLE II.

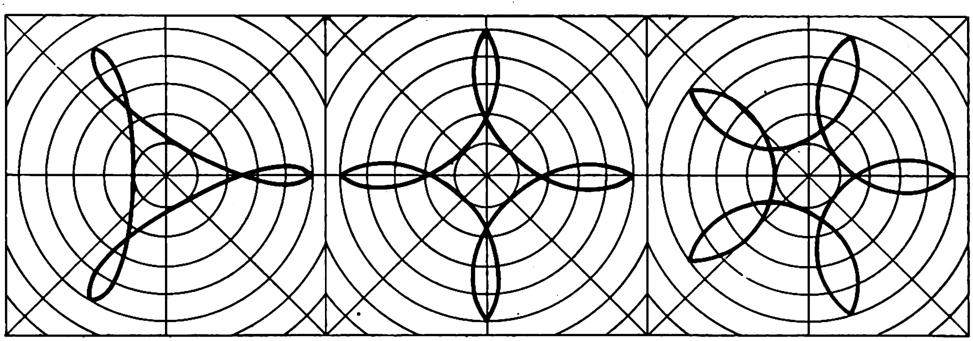
Max.	0°		90°		180°		270°	
Min.		45°		135°		225°		315°
Max.	360°		450°		540°		630°	
Min.		405°		495°		585°		675°

On the other hand when n is a fraction such $\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., a cycle of $2 \times 360°$ is necessary for θ to repeat itself, *i.e.*, for the pattern to be re-entrant. For example let $n = \dfrac{11}{2}$. The maximum and minimum values of r occur as shown in Table III.

TABLE III.

Max.	0°		80°		160°		240°		320°
Min.		40°		120°		200°		280°	
Max.		400°		480°		560°		640°	
Min.	360°		440°		520°		600°		680°

Here it is seen that for the same value of θ in space r is both a maximum and a minimum. Fig. 9 shows the nature of the pattern for $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., when the loops are made sufficiently small to reduce them to spots. Fig. 10 shows a photograph of the pattern observed on the cathode ray oscillograph screen when $n = \dfrac{13}{2}$.



$n = 2$ $n = 3$ $n = 4$

Fig. 14.

A general method of recognising easily

fractional ratios such as $\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, etc., may be formulated as follows. If the alternate loops or spots are connected by the path of the cathode ray as in Fig. 10, then the denominator of n is 2. The numerator is given by the number of loops or spots plus two when the spots are inside the pattern.

(2) Case when the Two Circular Motions are in Opposite Directions.

(*a*) *Equation for the pattern.*

Referring to Fig. 11, if the low frequency vector $\overline{OA}$ revolves in the counter-clockwise

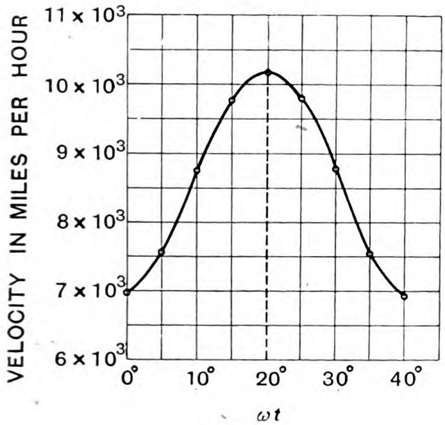


Fig. 15.

direction the high frequency vector must be considered in this case to revolve in the clockwise direction.

Then $\angle P'AB = -n\omega t.$

$$\therefore r = \{(a \cos \omega t + b \cos n\omega t)^2 + (a \sin \omega t - b \sin n\omega t)^2\}^{\frac{1}{2}}$$

$$= \{a^2 + b^2 + 2ab \cos \overline{n+1}\, \omega t\}^{\frac{1}{2}} \quad .. \quad (10)$$

$$\tan \theta = \frac{a \sin \omega t - b \sin n\omega t}{a \cos \omega t + b \cos n\omega t} \quad .. \quad .. \quad (11)$$

Equations 10 and 11 completely define the position of the cathode ray spot at any instant and the pattern can be plotted by giving values to ωt from 0° to 360°. Proceeding as before, it can be shown that the maximum and minimum values of r occur when $\theta = \frac{n'\pi}{n+1}$ or 0, and that at these values of r, $\theta = \omega t$.

For example when $n = 8$, Maximum values of r occur when $\theta = 0°, 40°, 80°, 120°, 160°, 200°, 240°, 280°$ and $320°$. Minimum values of r occur when $\theta = 20°, 60°, 100°, 140°, 180°, 220°, 260°, 300°$ and $340°$.

In Fig. 12 the pattern is plotted with the help of equations 10 and 11 for $n = 8$, $a = 4$ units of length and $b = 1$ unit of length.

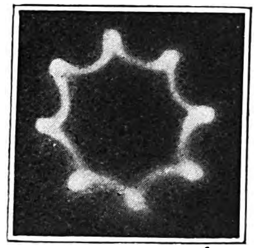


Fig. 16.

Fig. 13 is a photograph of the pattern for $n = 8$. Fig. 14 shows the nature of the patterns for various ratios. It must be observed that the patterns have loops outside, their number being $(n + 1)$. Conversely, when the loops are outside, as in Fig. 13, the number of loops minus one, gives the ratio of the two frequencies superimposed.

(*b*) *The velocity of the cathode ray spot along the pattern.*

The expression for the velocity is derived in a similar manner and is given by the equation

$$\frac{ds}{dt} = \omega\{a^2 + n^2b^2 - 2nab \cos \overline{n+1}\, \omega t\}^{\frac{1}{2}} \quad .. (12)$$

In Fig. 15 the velocity is plotted for values of ωt from 0° to 40°, *i.e.*, for one loop when $n = 8$, $a = 4''$, $b = 1''$ and $\omega = 2\pi \times 3{,}000$. It is observed that the velocity is a maximum when r is minimum and *vice versa*, so that here again the loops are brighter than other portions and the same advantages are obtained in the comparison of frequencies of high ratios as have been pointed out already.

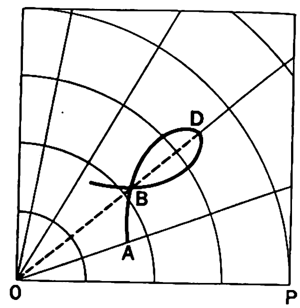


Fig. 17.

Fig. 16 shows a photograph of the pattern when $n = 7$ and when the loops are reduced to spots.

(*c*) *The size of the loops in relation to the ratio of amplitudes.*

Referring to Fig. 17 which represents one loop of the pattern, BD is the size of the loop according to the previous notation.

$$BD = OD - OB.$$

Considering OB, we have

$$OB = \{a^2 + b^2 + 2ab \cos \overline{n+1}\ \omega t_1\}^{\frac{1}{2}}$$

where ωt_1 is the angle of the low frequency vector pertaining to the point B. To find out how OB varies with $\frac{b}{a}$ it is first necessary

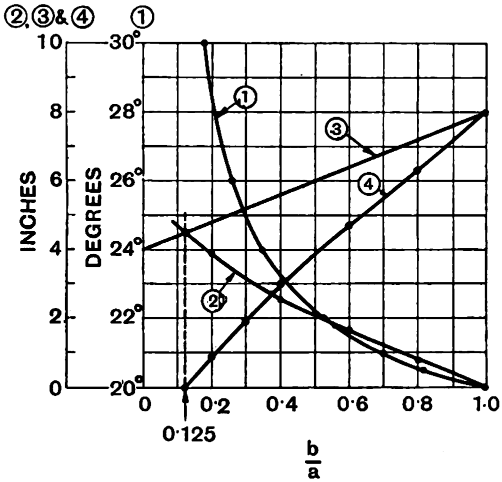


Fig. 18.

to determine how ωt_1 varies with $\frac{b}{a}$ for given value of n.

Proceeding as before,

$$\frac{b}{a} = \frac{\sin \omega t_1 - k \cos \omega t_1}{\sin n\omega t_1 + k \cos n\omega t_1}.$$

When $n = 8$, $k = \tan 20° = 0.364$.

$$\therefore \frac{b}{a} = \frac{\sin \omega t_1 - 0.364 \cos \omega t_1}{\sin 8\omega t_1 + 0.364 \cos 8\omega t_1} \quad \ldots (13)$$

Equation (13) which gives the relation between $\frac{b}{a}$ and ωt_1 is plotted in Fig. 18, curve 1 for values of $\frac{b}{a}$ varying from zero to unity.

Now

$$OB = a\left\{1 + \left(\frac{b}{a}\right)^2 + 2\left(\frac{b}{a}\right) \cos \overline{n+1}\ \omega t_1\right\}^{\frac{1}{2}} \quad \ldots (14)$$

Curve 2 in Fig. 18 is plotted with the help of equation (14) and curve 1 of the same figure. It shows how OB varies when $\frac{b}{a}$ varies from zero to unity assuming $a = 4''$.

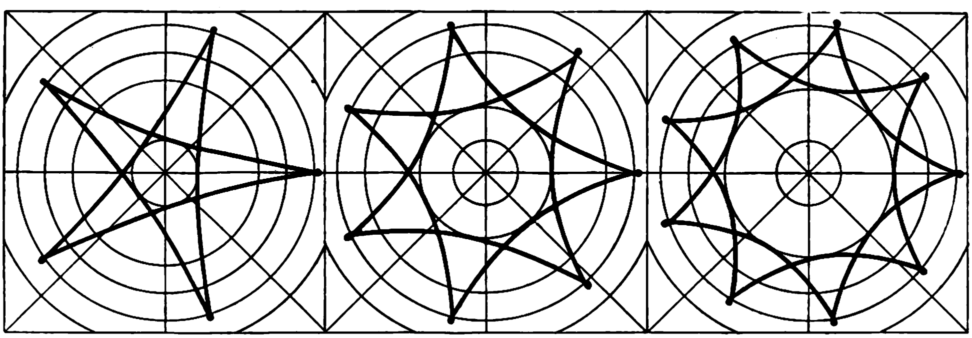
Let us now consider OD.

$$OD = a + b \text{ (since } D \text{ is a maximum point for } r)$$
$$= a\left(1 + \frac{b}{a}\right).$$

Curve 3 of Fig. 18 represents the variation of OD with $\frac{b}{a}$.

Finally curve 4 of the same figure is plotted from curves 2 and 3 with the help of the relation $BD = OD - OB$. This curve therefore represents how the size of the loop varies when $\frac{b}{a}$ varies from zero to unity.

Here again it is to be observed that when $\frac{b}{a} < 0.125$ the size of the loop is zero. Hence the minimum ratio of amplitudes for reducing the loops to spots is given by $\frac{b}{a} = \frac{1}{n}$ where n is the ratio of frequencies.



$n = \frac{3}{2}$ $\frac{b}{a} = \frac{2}{3}$ $n = \frac{5}{2}$ $\frac{b}{a} = \frac{2}{5}$ $n = \frac{7}{2}$ $\frac{b}{a} = \frac{2}{7}$

Fig. 19.

(*d*) *The form of the pattern when the ratio of frequencies is fractional.*

Equations 10 and 11 hold good even when n is fractional. The only important case in practice is when $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc. The nature of the expression

$$r = \{a^2 + b^2 + 2ab \cos \overline{n+1}\,\omega t\}^{\frac{1}{2}}$$

again suggests that for the same value of θ given by

$$\theta = \omega t = \frac{n'\pi}{n+1}$$

or 0, r is both a maximum and a minimum. Fig. 19 shows the nature of the patterns when $n = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc.

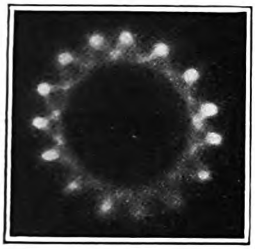


Fig. 20.

Fig. 20, shows a photograph when $n = \frac{13}{2}$. It is observed that alternate spots are connected and the number of spots when $n = \frac{13}{2}$ is 15. Hence, when the spots are outside, a general method of recognising fractional ratios such as $\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc., is as follows. The numerator of n is given by the number of spots minus two, and the denominator is 2 when the alternate spots are connected as in Fig. 20.

In conclusion, it is found that the method of analysis as outlined in this article enables one to predict the nature of the pattern for any complicated ratios of frequencies but such ratios are not so useful in practice as the simple ones $\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, etc.

Radio Frequency Phenomena Associated with the Aurora Borealis.

By F. Dearlove.

NEARLY everyone has noticed, at some time or other, the phenomenon known as the "Aurora Borealis" in the northern half of the globe, and as the "Aurora Australis" in the southern half, but it is not generally realised that the Aurora has any effect on the propagation of the electric waves used in radio communication, and it is with the hope that a little light may be thrown on this interesting subject that the following is written.

For the past eighteen months I have been installing radio stations operating on short waves, for the Grenfell Mission in Labrador, so that communication could be established between their hospitals, many hundreds of miles apart, and in doing this I have been in a position to observe the effects of the Aurora very closely, as it was one of the greatest obstacles to success.

Two Types of Aurora.

There are two types of Aurora, one which I shall call type "A," a very faint glow, generally seen in the Northern sky, but not necessarily so, extending faint streaks or fingers of pale greenish light in all directions, appearing at a great altitude, generally moving slowly though sometimes remaining stationary as a barely perceptible glow for the greater part of the night; the other, which I shall term type "B," usually appears suddenly in the Northern sky, and consists of undulating patches of vivid greenish light, moving at times fairly rapidly, and extending occasionally over the whole sky. This type appears to be fairly low, and in some instances has been observed only a few hundred feet from the ground. Though the greenish colour usually predominates, very exceptionally all the colours of the spectrum will radiate from a huge arc in the Northern sky making a truly awe-inspiring spectacle. Whilst type "A" appears slowly, and lasts anything from a day to a week, type "B" lasts but an hour or two, though it may recur many times during a manifestation in which type "A" predominates. The Aurora seems to be of comparatively rare occurrence outside Newfoundland and Labrador on the American side of the world, but in my experience type "B" has been of nightly occurrence for weeks together within those countries.

With regard to the effect of the Aurora on radio waves, in these days of Broadcasting, everyone has noticed periods of poor reception, but on short waves these are very common, and occasionally we have periods when no signals can be heard on any wavelength below one hundred metres. In Newfoundland and Labrador, however, a few weeks after the first radio station was installed, it was definitely decided that these periods coincided with the appearance of the Aurora Borealis on the one hand, and with a change in the weather on the other. Periods of poor reception due to changes in weather conditions could invariably be forecasted by careful barometric observation, but no such prognosis was possible for those due to the Aurora.

Putting on one side variations due to weather changes, we were left with periods of variable communicability, due to the Aurora affecting adversely both the transmitted and the received waves. In the endeavour to discover something on the subject the following facts were disclosed.

On the appearance of Aurora type " A," signals on forty and eighty metres underwent a very slow fading effect, and it would be almost impossible to communicate with anyone; this was particularly noted when, as sometimes happened, the Aurora appeared in the Southern sky, for signals would disappear entirely. Strangely enough, occasionally during this period the Aurora itself would be barely visible, but the effect persisted usually from two to three, though sometimes four and even occasionally five, days. The signals of the world's high-power stations would disappear, until " WIZ " alone was left with a most peculiarly thin reedy note, until finally, just before the signals disappeared entirely, it would be noticed that the dots and dashes had " tails " till the transmission resembled just a long-drawn-out wavering whisper, absolutely unintelligible.

On twenty metres the change which took place was rather different; for an hour or two after the Aurora type " A " manifested itself communication would be possible in many cases with stations whose forty metre signals had just disappeared, whilst stations which had been inaudible before the appearance of the Aurora would slowly appear and increase in audibility, whilst others would disappear completely. This would continue for a while, when it would be noted that the only stations to be heard would be ones at incredible distances, such as Asiatic, South American, and Pacific stations and, of course, at a time widely different to that at which those countries would normally be heard. As a matter of fact, the only Asiatic station ever heard on twenty metres was copied during one of these periods.

Though, of course, the Aurora was not visible in the daytime, its effect persisted, and it would be impossible to communicate with anyone, even stations usually easily worked during the daytime, local or long distant. A striking example of the effect of the Aurora type " A " on local signals was given when my portable station was taken out to a distance of ten to twelve miles, and its signals almost disappeared, whilst normally they were strong at that short distance and for a hundred miles further. Aurora type " B " would often be present during a manifestation of type " A," though, owing to the pronounced effect of the latter, it was difficult to observe any phenomena which could be attributed to type " B " alone.

When Aurora type "B" appeared alone, signals on forty metres at distances of two or three hundred miles would undergo pronounced fading, alternating with periods of just as pronounced amplification, the signal strength being in many cases three to four times as great as in normal conditions. Signals coming from stations at distances of three to four thousand miles would fade more slowly, but even they would experience the amplifying effect. This phenomenon would gradually give place to a condition when all signals would be unusually poor, for two or three hours, returning quickly to normal when the Aurora type " B " had disappeared. The effect of type " B " was easily proved to be quite local by the fact that an English station G 2XY, with whom I was working when the Aurora appeared, suddenly had difficulty in receiving my signals, whilst to me his also had become very faint, but he easily carried on a conversation with the Grenfell Mission main station NE 8AE, only two hundred and fifty miles to the south of my own station XNE 8FD, a portable

which I was carrying around Labrador for the purpose of ascertaining the best time for inter-communication. Before the appearance of the Aurora, NE 8AE's signal had been reported by 2XY as little louder than my own, and as the phenomena commenced my own signals were not readable at 2XY, but little diminution in signal strength, if any, was noticed at either NE 8AE or 2XY on each other's signals. Very little effect on twenty metres was noticed when Aurora type "B" was present, neither was any effect noticed on very local signals, at a distance of ten or twelve miles or so, on forty-five metres. They did, however, affect the Broadcast bands where reception would be exceptionally poor when either type was present.

It was noticed particularly that the effect of either type of Aurora was always accentuated when it appeared in the path of the received signals, whilst with type "B," when the Aurora was in the opposite direction to that in which it was desired to communicate, though signals would not appear to be very much affected by the Aurora, it would be absolutely impossible to work any station on forty metres and with the utmost difficulty on twenty.

It must be noted also that, although naturally the effect of the Aurora was usually observed to begin at night, when the same was visible, yet when fading effects such as were known to be identical to those produced by the Aurora occurred in the daytime, as night drew on the latter would invariably be in evidence. In the rare cases when this was not so, it was due to poor visibility owing to low lying mist or fog, which is very prevalent during the spring and summer in both Northern Newfoundland and Southern Labrador.

Although many observers state they have seen the Aurora type "B" accompanied by a faint crackling sound as of an electric discharge, this has never been my experience, and, moreover, the radio phenomena associated with the Aurora of either type are usually noted particularly to take place with a complete absence of static or atmospheric disturbances.

From the foregoing observations it will at once be apparent that the Aurora type "A" is the one we are most concerned with as affecting the propagation of Radio waves to the greatest extent. This type, appearing as it does at a great altitude, seems to be capable of producing an accentuated "daylight" effect, the fading out of forty and eighty metre signals completely at any great distance, the complete absence of skip distance on those waves coupled with the extremely short distance workable, and finally the enormous skip distance noticed on twenty metres. For the daylight effect we have the Kennelly-Heaviside layer theory, whilst, as far as I am aware, for the effect of the Aurora we have none, and yet the effect of the latter, though accentuated as compared to that of daylight, is identical to it. I think we may take it that ionisation takes place to a rather unusual extent. It has been clearly shown that the propagation of the waves is not affected, apart from using an actual reflector, except by a change in the medium—*i.e.*, the ether, such as takes place during ionisation by ultra-violet or polarised light. The light given off by the Aurora seems to contain very little ultra-violet component, as its actinic effect is but slight, or it may be that absorption takes place before it reaches the surface of the earth; it is but feebly polarised, as is that of the moon, whilst its effect is out of all proportion with that of the latter, which cannot be determined even after twelve months' observation, and out of all proportion also, within the sphere of its influence at least, with the daylight effect, caused by ionisation due to radiation of ultra-violet and other rays from the sun, though it is easily shown that the sun's Corona (visible only during an eclipse, but shining all the time nevertheless) gives off more ultra-violet light in five minutes than the Aurora or the moon could do in twelve months.

It is with a feeling of regret that I must admit I am no nearer the solution of the mystery than when the observations began, I am not a physicist by any manner of means, but I present these notes in the hope that they may at least be of interest if not of actual utility to those who, like myself, have the interests of radio-communication at heart.

The Operation of Several Broadcasting Stations on the Same Wavelength.

Paper by Capt. P. P. Eckersley, M.I.E.E., and A. B. Howe, M.Sc., read before the Wireless Section, I.E.E., on 6th March, 1929.

ABSTRACT.

Section I.

Theory of Single Wavelength Working for Broadcasting Stations.

In an introductory portion the authors point out that sharing one wavelength between several stations, either in the same or in different counties, is of considerable help in making the best use of the wavelengths available for broadcasting services, and briefly discuss the subject of wavelength allocations.

TABLE I.

Point.	Condition.	Result to a receiver installed at the given points.
C & E	Zero energy.	No reception.
D	Strong side-bands. No carrier.	Carrierless telephony and distortion for ordinary reception.
F	Double carrier and double sidebands.	No distortion.
G	Strong carrier and No sidebands.	No modulation.
H	Elimination of one sideband; relative strengthening of other	Distortion with most types of detector.

both is appreciable. Assuming the stations of equal power, to be exactly synchronised, and to be modulated by the same low frequency, f_m, frequencies of f_c $(f_c + f_m)$ and $(f_c - f_m)$ will be set up with corresponding wavelengths λ, λ_1 and λ_2. For a 150 k.c. per sec. carrier (2,000 m.)

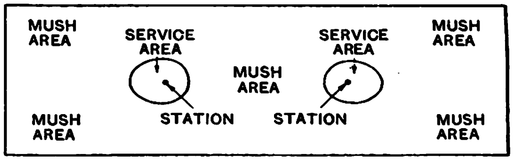


Fig. 2.—*Showing small service area and large "mush" area (where quality of transmission is bad) around two stations sharing the same wavelength.*

modulated at 10,000 k.c. per second, the interference conditions resulting are as shown in Fig. 1*, and the states at certain points are set out in Table I.

As we move away from close proximity to one station towards the other, the distortion produced by the interference pattern becomes more and more appreciable until a point is reached at which the interfering station produces noticeable distortion and we may say that we can no longer expect good service from the nearer station. There will be around each station an area in which the distortion will not be noticeable, but there will also be a large area where service conditions cannot be said to exist, as shown in Fig. 2.

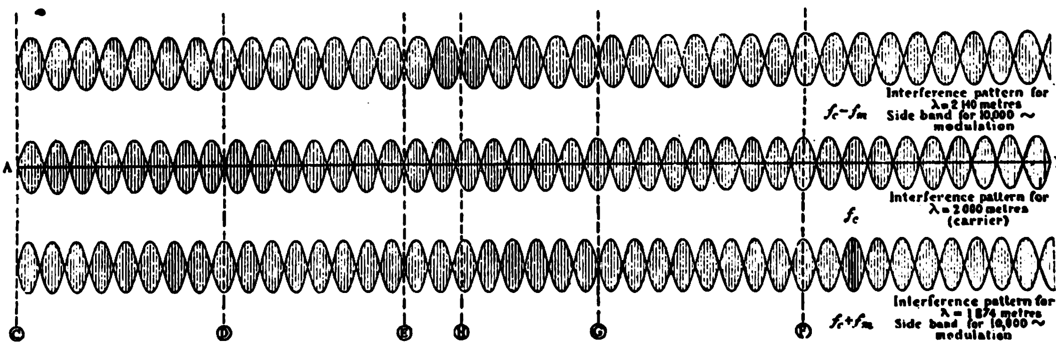


Fig. 1.—*Interference pattern produced by two broadcasting stations using the same wavelength of* 2,000 *m. and having the same modulation of* 10,000 *cycles per sec.*

They then proceed to the theory of single wavelength working.

If two broadcasting stations emit carrier waves of identical frequency, an interference pattern will be set up in areas where the field strength of

*The author's original figure numbers are adhered to throughout this abstract.

EXPERIMENTS TO TEST GENERAL THEORY AND DETERMINE EMPIRICAL QUANTITIES.

Experiments to determine the boundaries of the service area were conducted from 5GB and 5IT (the local Birmingham transmitter, not now used), with exact synchronisation of the carrier, simultaneous modulation by identical or by different programmes, and with exploration of the territory between the stations. 5GB had 20 kW. aerial power and 5IT had 1 kW., each at 610 k.c. (491.8 m.), the frequency being controlled by a 305 k.c. transmitter at Daventry. This transmission was picked up by 5GB and 5IT and used through a frequency doubler to produce the carrier of 610 k.c. per second.

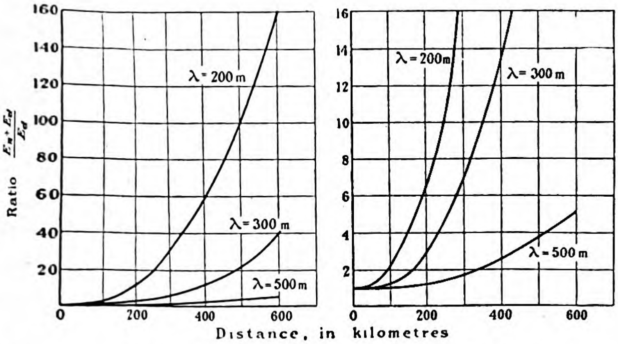


Fig. 5.—*Curves of maximum fluctuation of signal expressed as a ratio to unity for various wavelengths against distance from station.*

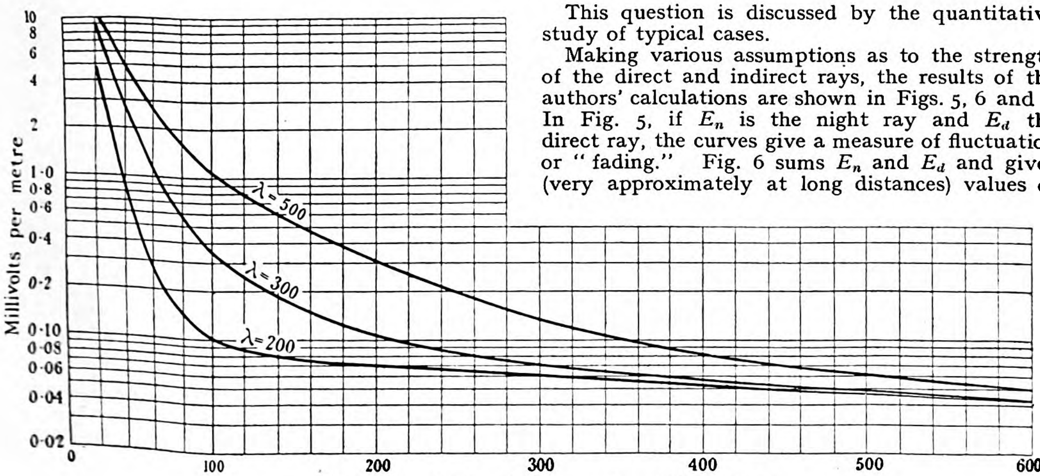


Fig. 6.—*Variation of total radiation* ($E_d + E_n$) *with distance* 1 *kW. radiated.*

It was first determined that, without modulation, there was a stationary interference pattern. Arrangements were made for 5-minute periods of radiation of the same programme by both stations, interspersed by 5-minute periods of radiation of the programme by one or the other singly. Distortion was noticed, as was to be expected, where the field strengths of the stations were comparable. Even within the "mush" area, however, it was possible to receive good quality, but theory indicates that good reception in a "mush" area is possible, although fortuitous.

It was found that when the strength of one station at a point was five or more times that of the other, reception from the former was normal. In other words, the service area of station A is found by drawing a line through the points where the field strength of A is 5 times that of B, and vice versa.

If the stations are not exactly synchronised, but differ by an amount Δf, which makes a beat between carrier waves so slow as to be below audition, say, 20 cycles p.s., the effect is as if a receiver passed through the states C to H (of Fig. 1) consecutively, at a velocity determined by the frequency difference. It was found that if Δf was greater than 5 cycles p.s., the strength of one station had to be, at the boundaries of the service area, at least 10 times greater than the other to preserve good quality—as compared with a factor 5 obtained for perfect synchronisation.

If different programmes were radiated, it was proved that the strength of one station at a given point had to be 100 to 200 times that of the interfering station. The service area of a station sharing a wave with another is thus much less if each station transmits a different programme.

THE RANGE OF STATIONS SHARING WAVELENGTHS.

This question is discussed by the quantitative study of typical cases.

Making various assumptions as to the strength of the direct and indirect rays, the results of the authors' calculations are shown in Figs. 5, 6 and 7. In Fig. 5, if E_n is the night ray and E_d the direct ray, the curves give a measure of fluctuation or "fading." Fig. 6 sums E_n and E_d and gives (very approximately at long distances) values of the maximum radiation from a station radiating 1 kW. Fig. 7 gives the range of two stations sharing one wave, for complete synchronisation (factor 5) and for imperfect synchronisation (factor 10). From this it can be seen that, with large

separation of stations, it is better to use long wavelengths, while if the indirect ray no longer plays a part (*i.e.*, where the stations are close together) the short wavelength gives a better service range.

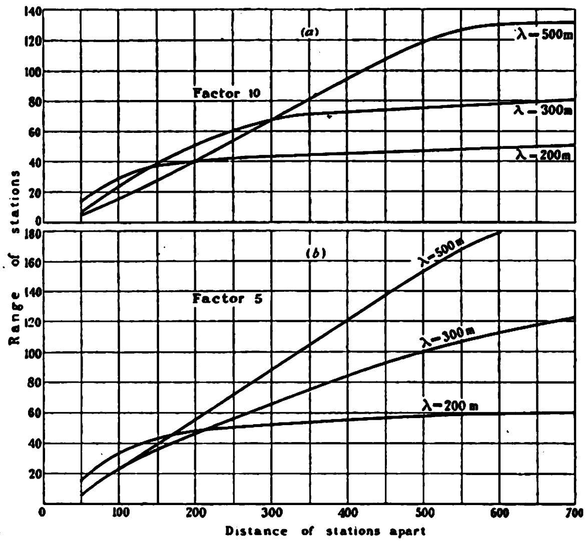


Fig. 7.—*Range of two equal power stations sharing same wavelength, at different distances apart and different factors.*

The case of more than two stations sharing a wave is then discussed, and a model described in which a number of alternators (up to 18) were employed to represent different stations. It is concluded that in practice the range of a station sharing a wavelength with others will not be seriously decreased after more than 6 or 7 stations share the wave, because the probability of the averaging out of the peaks of field strength is greater with more stations. No doubt large peaks will occur, but at such rare intervals that the listener will not notice their occurrence.

As a general conclusion, the authors infer that waves shared between local low-power stations will be useful to cover large towns with good conditions of broadcasting if such towns happen to be outside the range of high-power regional stations.

Section 2.

This section discusses the practical question of synchronising the stations involved. Three general methods are possible :—

(1) By a C.W. transmitter giving a steady radiation of frequency f_d, which is received by the broadcasting stations and multiplied n times, so that $nf_d = f_c$.

(2) By supplying, *via* landline, a steady low-frequency f_l, which is multiplied n times, so that $nf_l = f_c$.

(3) By supplying separate drives so accurate and so carefully calibrated that synchronisation is given without any common source of master frequency.

Method (1) would involve a powerful long-wave transmitter, with obvious difficulties. Method (2) is practicable, but any sudden change of line constants would produce large relative phase changes in the carrier. Method (3) involves facing the factor 10 and finding a source which can be maintained to 1 part in 150,000. Even methods (1) and (2) still involve a source accurate to 1 in 100,000. The B.B.C. have based their system on method (3), using tuning-fork control. The fork is made by the Marconi Co. The change in frequency is about $\frac{1}{8}$ cycle per degree C., with automatic control of the temperature.

The frequency of the forks is 1,015.625 cycles per second. This is passed through a series of frequency-doublers, and brought up to 1,040 k.c./sec. There are thus 10 stages of frequency-doubling, using, in all, about 25 valves.

At the time when this paper was written, four such sets were working in Great Britain—*i.e.*, at Edinburgh, Hull, Bradford and Bournemouth. It is the intention of the B.B.C. in time to equip 10 stations with similar gear and to achieve thereby a measure of single wavelength working.

Results of Practical Working.

While the Bradford station formerly shared a wave with other European stations, transmitting different programmes and badly synchronised, it had a range of $\frac{1}{2}$ to $\frac{2}{3}$ km. Now, on the same programme as the other British stations sharing the wave, it has a range of 10 km. Considering the local density of population, the number of extra listeners brought into "A" service area conditions is enormous. The range of Hull has been raised from 2 km. to 10 km. Bournemouth appears to be satisfactory up to 20 km. and Edinburgh up to 10 km. It is, as yet, too early to define service and "mush" areas, but the relay station is again a useful unit in the B.B.C. system.

The authors conclude that in Britain, the method bids fair to restore service to all relay stations which were formerly hopelessly jammed when working on international common waves. Even with regional stations, single wavelength working may make for an economy in the use of wavelengths and still continue service to isolated towns not sufficiently covered by regional stations.

Amongst general conclusions on common wavelength working, the authors also suggest that it is useless in a Continent to share wavelengths between stations belonging to different nationalities or groups.

DISCUSSION.

The discussion which followed the reading of the paper was briefer than usual.

In opening the discussion Mr. T. L. Eckersley congratulated the authors on the closeness of frequency attained. He thought that they had not put sufficient stress on the necessity for absolute synchronisation, and showed the distorting effect of beating due to the sidebands from a transmitter slightly detuned, which would not result with perfect synchronisation. He criticised the calculation of the strength of the indirect ray, used

in the construction of Figs. 4, 5 and 6, and quoted recent measurements of the downcoming ray.

MR. LUCAS said at the time of these experiments the choice of tuning fork was no doubt justified, as the piezo-crystal was not then stable as a frequency control. He then referred to recent progress in crystal control, more especially in America. As a modern frequency standard 1 in 100,000 was attainable and he had watched three for two years and had been unable to detect variation greater than this value. As a frequency control the crystal had the advantages of very small temperature coefficient, *i.e.*, 2 in one million, while it also shifted the standard directly into the radio frequency gamut. He suggested that this might have been used with a considerable reduction of the stages necessary to attain the final frequency. There was perhaps the disadvantage to crystal control of the difficulty of adjusting crystals to each other which might not be possible to better than 5 in a million.

MR. R. H. BARFIELD suggested that directional reception might advantageously be used to eliminate the interfering station on the common wavelength. This, however, involved frame reception while the use of aerials was more general. He also suggested altering the polar diagram of one station so as to give a blind spot from it near to the other town on the common wavelength. This might be done by a tuned aerial suitably placed, a rough calculation of the effect of this being quoted.

DR. E. H. RAYNER asked for information as to how the authors would allocate wavelengths to different stations in a small country. As regards the effect of several stations on the same wave, he compared the net result to that of an orchestra, where it was known that the effect varied with the square root of the number of instruments.

MR. J. F. HERD criticised the use of the word synchronisation as employed by the authors to mean identity of frequency. Synchronisation also involved identity of phase. He also referred to the type of polar curve mentioned by the authors as semi-circular. Doubtless they referred to the type of polar curve quoted in a previous paper, but the point should be made clear.

DR. D. W. DYE said he was still convinced that the tuning fork was a standard of very high accuracy, despite the fact that it involved the large number of stages necessary. He was surprised at mild steel being used instead of elinvar, and was doubtful if the damping was best in mild steel. A good deal of work had still to be done on mechanical oscillators. The use of the large number of stages could be avoided by a special circuit for harmonic multiplication, and he illustrated a circuit for the production of a fundamental and a harmonic. The fifth harmonic had been found possible to pick out in this way. He also suggested that the condition of stationary waves (shown in Fig. 1) might be utilised for experimental measurement of wavelength.

CAPT. P. P. ECKERSLEY briefly replied to the discussion. In reply to Mr. Lucas, he said that the tuning fork had proved very satisfactory in practice as a frequency standard. In reply to Dr. Rayner he outlined a scheme of wavelength distribution in a small country for a common wave and for an exclusive wave (as for a regional station) and discussed the extension of the principle to adjacent countries.

On the motion of the Chairman (COMMANDER J. A. SLEE, C.B.E.) the authors were cordially thanked for their paper.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Output Characteristics.

To the Editor, E.W. & W.E.

SIR,—In the summary of the article on "Output Characteristics of Thermionic Amplifiers" it is stated that the method of using plate current/plate voltage characteristics for combining the characteristics of a valve and its output circuit is due to Messrs. Warner and Loughren.

I should like to point out that Capt. H. J. Round was using this method in 1919. In the *Journal of the Institute of Electrical Engineers* for March, 1920, there is a paper by him on "Direction and Position Finding"; and as Appendix II of this paper he dealt with the case of a simple resistance amplifier, by means of plate current/plate voltage characteristics. In 1923 he explained the method to me, and realising that it might be of value to others, I set myself to write out and to some extent apply his method to various cases. The resulting article was accepted by the Editor of *E.W. & W.E.* in December, 1924, but it was not published until July and August, 1926.

E. GREEN.

Chelmsford.
1st March, 1929.

Effect of Anode-Grid Capacity in Detectors and L.F. Amplifiers.

To the Editor, E.W. & W.E.

SIR,—Mr. Medlam, in his reply to my criticisms of his article on the above subject, says that my letter contains a whole series of unfortunate assumptions, but omits to mention any but the first "term" of the "series." This, it appears, is that I assumed that he was led to his conclusions as the result of a mathematical analysis. I think I may be pardoned for this particular "assumption," for, though he now states that he first became aware

of the distortion experimentally, he certainly did not give the impression that his article was merely intended to account theoretically for certain experimental results. On the contrary, without any prior reference to experimental work, he stated: "In the present article the effects of the anode-grid capacity on the audio-frequency characteristic of the detector and L.F. stages are shown to be serious." The method of showing it was by a mathematical analysis, not by a presentation of any experimental data, and it was as a mathematical analysis, therefore, that I criticised it. As such, I think it is quite legitimately open to criticism, whether it be intended to deduce certain previously unknown facts, as I thought, or merely to account theoretically for certain observed results.

If the distortion which Mr. Medlam says he has observed in anode-bend detectors is really due to feed-back, the fact is certainly not accounted for by his theoretical investigation, which is unsound in more respects than I realised when I wrote my previous letter.

Mr. Medlam admits that the equation $e_r = \omega L_e i_g$ should read $e_r = L_e \frac{di_g}{dt}$, but on correcting for this he still finds an expression for E_g which indicates a large reduction of the carrier-wave input voltage due to feed-back, *even with such a very small value of* μ *as* 0.15. This is one of his deductions which I query. That there may be a very large reduction of the carrier-wave input voltage with a normal value of μ I quite agree, but not, I contend, with a valve operating under such conditions as to have such an abnormally low value of μ as 0.15.

The experiments he cites showing a reduction of the input voltage by feed-back to some 5 or 10 per cent. are for valves operating with a normal value of μ, but if we substitute, say, $\mu = 10$, in his amended formula for the carrier-wave input voltage, we find $E_g/E = 0.0090$—*i.e.*, an input voltage less than one-fifth of the lowest of the above-mentioned experimental values. This is the "enormous reduction" which I referred to in my letter.

The reason that Mr. Medlam's analysis leads to such a result is on account of his entire neglect of the effect of the resistance of the input circuit, a point to which I referred in my previous letter. I did not press the point because, on finding the other error which has now been corrected, I did not examine very closely the subsequent mathematical work and accepted his statement that the resistance terms in his expression for the impedance of the tuned circuit to the feed-back voltage could be neglected. Closer examination reveals that this is by no means the case. Though these terms —with a resistance of 10 ohms—are only about 4 per cent. of the terms which Mr. Medlam retains, they cannot be neglected for the simple reason that the coefficient k_2 vanishes at the carrier frequency when those terms are neglected. If they are retained, the correct value of k_2, with the above resistance, is not zero but 0.440, which is considerably larger than the corresponding value of k_1, namely, -0.091. Consequently, the ratio E_g/E, with $\mu = 0.15$, comes out at 0.895 instead of 0.377.

This, of course, is not really the correct value of E_g/E because, as it is now evident that the resistance of the input circuit cannot be neglected, Mr. Medlam's equations

$$\frac{dv}{dt} = \frac{i}{C_{ga}} + L_e \frac{d^2 i_g}{dt^2}$$

and
$$e_r = L_e \frac{di_g}{dt}$$

are no longer even approximately valid and must be replaced by the equations

$$\frac{dv}{dt} = \frac{i}{C} + \frac{de_r}{dt}$$

and
$$LC \frac{d^2 e_r}{dt^2} + rC \frac{de_r}{dt} + e_r = L \frac{di_g}{dt} + ri_g$$

The substitution of these equations does not lead, as Mr. Medlam suggests, to a differential equation of the fifth order with 2,146 terms in the coefficient of $\frac{d^4 e_g}{dt^4}$, but to an equation of the third order involving e_r and e_g, quite a respectable equation containing only a few additional terms in the coefficients.

If we then use Mr. Medlam's equation (11), $e_g = (e - e_r)$, we obtain a solution of the same form as his with the following expressions for k_1, k_2 at the carrier frequency under the particular tuning condition which he uses.

$$k_1 = -\left\{\frac{C_{ga}}{(C_{ga} + C_a)} + \frac{rr_a}{\omega_c^2 L^2}\left(\frac{C_a}{C_{ga}} + 1\right)\right\}$$

$$k_2 = \frac{r}{\omega_c L}\left\{\frac{C_{ga}}{(C_{ga} + C_a)} + \frac{1}{\omega_c^2 L C_{ga}}\right\}$$

As a matter of fact, Mr. Medlam's equation (11) is not strictly correct, because it omits to take into account the fact that the input voltage is modified to some extent by the introduction of the A.C. anode resistance of the valve when the latter is lighted, quite apart from the effect of the feed-back voltage e_r.

The equation should therefore strictly be $e_g = (e_1 - e_r)$, where e_1 denotes the modified value of e due to the valve resistance, and the solution mentioned above really gives the ratio E_g/E_1. This, therefore, requires to be multiplied by E_1/E to obtain the total effect produced by the valve when its filament is energised. This latter ratio can be obtained quite independently. Its value for the carrier frequency in the same example is 0.982, while the ratio E_g/E_1 is 0.971, so that $E_g/E = 0.953$. This is identical, to three places of decimals, with the value which I find by my method, the figure of 3 per cent. increase of resistance mentioned in my previous letter being for an input circuit resistance of 15 ohms.

If we take normal values of μ and r_a of, say, 10 and 25,000—which appear to be quite possible values under anode-bend rectification conditions, judging from an examination of the characteristic curves of some well-known makes of valves—we find from the formulæ for k_1, k_2 above, $E_g/E_1 = 0.116$, while the ratio E_1/E is 0.932, so that $E_g/E = 0.108$, which is again exactly the value I find from my formula.

Thus Mr. Medlam's method, when corrected to

allow for the effect of the resistance of the input circuit, leads to results as regards the reduction of input voltage at the carrier frequency which are in entire agreement with those derived by my somewhat different method. Incidentally, the fact that the values of E_g/E calculated by the two different methods agree so exactly is in accordance with Mr. Medlam's observation that the effect of retuning is in this respect negligible, but it still appears to me quite possible that the omission to retune may cause to some extent an unsymmetrical variation of input voltage with side-band frequency on opposite sides of the carrier frequency.

From the above it is clear, I think, that there is perfectly satisfactory general agreement between theory and experiment as regards the effect of the feed-back on the carrier-wave input voltage. Mr. Medlam does not appear to realise, however, that this effect in no way indicates distortion, but is entirely in accordance with my theoretical conclusion that the effect of the feed-back is solely to cause an increase of the effective resistance of the input circuit. As I have shown in my article, the input voltage is nearly inversely proportional to $\sqrt{\frac{r_0^2}{r^2} + 4\frac{m^2L^2}{r^2}}$, where r_0 denotes the effective resistance of the input circuit as modified by the feed-back. Therefore, when Mr. Medlam finds, in his experiment with a P.M.4DX valve, that the carrier-wave input voltage is reduced, by the feed-back, to 50 per cent. of its original value, $\frac{r_0}{r} = 2$ and the ratio E_g/E for a side band corresponding to an audio-frequency of 8,000, with a radio-frequency of 800 kc., $r = 10$ and $\omega_c L = 1{,}500$, is $\sqrt{1 + 4\left(\frac{150}{100}\right)^2} \Big/ \sqrt{4 + 4\left(\frac{150}{100}\right)^2} = 0.877$.

Thus there is a comparatively small reduction of the input voltage at frequencies correspondingly to the higher audio-frequencies. This does not indicate distortion, but, on the contrary, a *reduction* of the distortion which in any case results from the selectivity of the tuned circuit. If the selectivity of his input circuit is greater than is represented by the value $\omega_c L/r = 150$ used above, there would be still less reduction of the input voltage at the higher audio-frequencies than is indicated above. Also, as Mr. Medlam does not retune his circuit to allow for the detuning effect of the feed-back, it is quite possible—in fact, I think, probable—that he may find different values of input voltage for corresponding positive and negative side bands. Mr. Medlam says that the question of the distortion of the L.F. current wave-form in the anode circuit is "outside bounds." Why? The object of his article was, in his own words, to show that "the effects of the anode-grid capacity on the *audio-frequency* characteristic of the detector and L.F. stages" are serious. The italics, which are mine, are sufficient comment on this point.

Lastly, Mr. Medlam thinks his reply makes it unnecessary for him to comment on the theoretical results which I claimed to have obtained and by way, I suppose, of indicating *his* opinion of the value of those claims remarks that on this matter he will "only take up the statement to the effect that the rectified current of modulation frequency is proportional to the square of the input modulation voltage."

This is indeed a curious comment, because reference to my letter will show that I said nothing which could possibly be construed as meaning what the above alleged statement means, and made no reference at all to the specific relation between the quantities mentioned! The only explanation I can think of for this comment is that Mr. Medlam saw the original draft of my article, where the question is discussed, but he must have given it scant attention or he would never have alleged such a statement, as will be seen when the second part of the article is published. In any case, to comment on a statement which has not yet been published is very decidedly "outside bounds."

E. A. Biedermann.

Brighton.

The Transmitting Station actually sends out Waves of One Definite Frequency, but of Varying Amplitude.

Sir,—My thanks are due to Mr. A. B. Howe for his letter published in the February issue, not only for satisfactorily clearing up a point which has occasionally puzzled me in idle moments, but also for the manner in which he has done so.

From my point of view it is clearly unfortunate that I made no mathematical analysis of the problem, seeking instead some physical explanation. The difficulty, however, appeared to commence with the introduction of mathematical analysis, and this did not encourage further investigation. It would seem that I have displayed that little learning which is proverbially dangerous.

The analysis contained in the letter of Mr. E. A. Biedermann, published in the March issue, is substantially similar and calls for no further comment. He also takes me to task for not unquestionably accepting a mathematical conclusion. I do not wish to disparage the use of mathematical investigation in physical problems, but unhesitatingly say that in such cases the final test should be a physical one. It is not uncommon for mathematical results to be rejected or tacitly ignored for physical reasons.

The simple formula for the resonant frequency of an oscillatory circuit, obtained mathematically, gives it as the square root of a product. Now we learn very early that a square root is either positive or negative. Thus the mathematical investigation gives in addition to the correct result an alternative one, which, in our world at least, has no physical interpretation whatever.

As a result of the correspondence I shall await with renewed interest any answer to the original challenge of Mr. A. W. Ladner to explain single side-band working on a single frequency basis. The case of suppressed carrier—*i.e.*, double side-band working is comparatively simple.

Frank Aughtie.

Abstracts and References.

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PROPAGATION OF WAVES.

SHORT WAVE ECHOES AND THE AURORA BOREALIS.—L. H. Thomas. (*Nature*, 2nd February, 1929, V. 123, p. 166.)

Referring to the suggestion made independently by van der Pol and Appleton (February Abstracts, pp. 97, 98) that the Störmer echoes might be explained by the disturbance spending a long time in a region containing so many electrons per c.c. that the group velocity of the disturbance was very small, the writer evaluates the resulting signal intensity, using the expression given there by Appleton combined with an equation of his own giving a value for f. Assuming Pedersen's value (1.2×10^7) for the velocity of the electron under the supposed conditions, a delay of 10 seconds would reduce the signal intensity to $e^{-125000}$ of its initial value. "The suggested explanation seems, therefore, to be untenable, unless it is assumed that v is much larger. If v were 30 times as large ($v = 3.6 \times 10^8$, corresponding to 37 volts) the minimum reduction for a 10-second delay would be to $e^{-4.6}$ ($=1/100$) of its initial value. The above objection does not apply to the second explanation put forward by Professor Appleton."

THE ELECTRICAL CONDUCTIVITY OF THE ATMOSPHERE AND ITS CAUSES.—V. F. Hess. (Review of English Translation, *Nature*, 2nd February, 1929, V. 123, pp. 155–156.)

The reviewer states: "Of the causes which produce ionisation, the most important is the highly penetrating radiation discovered by Hess himself, and to many readers the section dealing with this radiation will prove the most interesting part of the book. . . . It is to be noted that Hess still regards it as possible that the ultra-gamma radiation is produced in the outer atmosphere of the earth in response to some stimulus from the sun. He suggests that measurements of the penetrating radiation in the auroral zone would settle this question. Less cautious philosophers are convinced that the radiation comes from distant space." The reviewer himself, after quoting Jeans, suggests that there is no reason to doubt that some day we shall have telescopes designed to give measurements of the ultra-gamma radiation from individual nebulæ, measurements which will lead to new knowledge of the structure of the universe. Turning to the main subject of the book, he quotes: Near the ground, the conductivity of the air is such that the half-time period for the dissipation of the charge on an exposed conductor is roughly 15 mts. At 9 km., the air conducts 10 times as well. The small ions to which the conductivity is due have but short lives—their usual fate is to be caught by the Aitken nuclei within a minute after their creation. On land, they are mostly generated by radioactivity—about 8 ions per c.c. per sec. by this (5 by α, 3 by γ rays) and $1\frac{1}{2}$ by ultra-gamma radiation. Over the oceans, the latter is the (main ?) cause.

"The important subject of the ionisation of the upper layers of the atmosphere is dealt with very briefly. . . . The sketch of the part played by the Heaviside layer in the transmission of wireless waves is brought up-to-date, but there is no account of the evidence from terrestrial magnetism for the existence of such a layer. . . . It is hoped that in another edition some account of the brilliant work of Schuster and Chapman in elaboration of Balfour Stewart's idea will be given."

MEASUREMENTS OF THE AMOUNT OF OZONE IN THE EARTH'S ATMOSPHERE AND ITS RELATION TO OTHER GEOPHYSICAL CONDITIONS. PART III.—G. M. B. Dobson, D. N. Harrison, and J. Lawrence. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 456–486.)

Parts I and II were published in 1926 and 1927. The main object of the research was to study the distribution of ozone in cyclones and anticyclones: seven stations in different parts of the world collaborated in the work. Daily ozone observations show that there is a well-marked area, with much ozone, immediately to the west of cyclones; ozone is generally small in anticyclones. Among the mass of detail contained in the present part, the following points may be mentioned: It is shown that there is no appreciable change in the relative energies of the wavelengths used, as emitted by the sun. In general, the ozone values deduced from measurements of different pairs of wavelengths agree very closely, but occasionally small differences —the reason for which is not yet known—appear and continue roughly constant for a few days. Effect of different latitudes on the annual variations: in the autumn all stations have roughly equal ozone values, while in the spring the northern stations have much more ozone. 1927 results confirm that there is a small but definite tendency for days with much ozone to be associated with magnetically disturbed conditions. But comparison of the *mean* ozone values (for N.W. Europe) with the *mean* magnetic character for several stations in the same region, instead of showing a still closer relation, shows no relation at all: this result is not yet understood. A depression is associated with a fall in ozone, followed by a sharp rise: there is a negative correlation between the amount of ozone and the temperatures up to a height of 8 km. Previous hypotheses (in the first papers) as to the cause of the relation between the

amount of ozone and the temperature and pressure in the troposphere are abandoned in favour of the view that the variations are due to the transportation, from one region of the globe to another, of large masses of air, including the whole atmosphere up to at least the height of the ozone layer. "The origins of the air currents in the upper part of the troposphere have a close connection with the fluctuations of ozone, polar air having a high ozone content and tropical air a low ozone content. This is the more interesting when we remember that the ozone is probably all in the stratosphere, the measurements indicating a height of about 40–50 km. for the centre of gravity of the layer (the base of the stratosphere being at a height of roughly 10 km.). . . . The ozone measurements thus give evidence that the great polar and tropical air currents extend to a great height and bring their own stratosphere with them, if we suppose that they retain their original ozone contents as they travel." Contrary to the usual idea that the chief cause of the formation of ozone is the sun's ultra-violet radiation, it is more in accordance with observation that the main effect of sunlight is the decomposition of the ozone already formed by some other cause (electric fields ?); though this decomposition is very slow, the change in one day being hardly detectable. (But Chalonge's moonlight observations, indicating a greater amount of ozone by night than by day, will—if confirmed—demand a very rapid drop about sunrise.)

Untersuchungen über die Ausbreitungsvorgänge ultrakurzer Wellen (Investigations into the Propagation of Very Short Waves).—F. Gerth and W. Scheppmann. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 23–27.)

Previous tests of various workers have led to the assumption that waves below 10 metres follow the laws of propagation of light; this paper describes tests undertaken to confirm this. They were between ground station and aeroplane and between the summit (and other points) of the Brocken mountain and the surrounding neighbourhood. Like light, these (3-3.20 m.) waves are screened by obstacles large compared with their wavelength; only a small fraction is diffused into the shadow zone. The amplitude decreases as the square of the distance in the region of the direct ray: outside this, it falls off very quickly. Unlike waves longer than 10 m., these waves have up to the present been found free from fading phenomena; apparently therefore there is no re-radiation from the upper atmosphere. From geometrical reasoning, the maximum distance for transmission of the direct ray is given by the equation $x = 3550 (\sqrt{h_1} + \sqrt{h_2})$ in metres, where h_1 and h_2 are the heights of transmitter and receiver above the earth's surface. Although both in the aeroplane tests and in the mountain tests the theoretical values were never quite reached, results agreed generally with the theory. Particularly striking was one mountain test, in which when a certain critical distance was reached (80 km., compared with about 110 km. calculated), an 80-fold increase of transmitting energy hardly increased the range at all; showing that the direct (straight line) ray is mainly responsible for the range, the small increase obtained by the higher power being due to the fact that in the region of diffused radiation the threshold of receptivity is reached sooner by the smaller power than by the larger. In the path of the direct ray the use of a receiving aerial had no effect; in the diffused ray region, it increased the range by a few kilometres. The writers lay stress on the importance of these waves as a means of communication for special purposes, the outstanding points being *the definite limitation of their range*, the possibility of concentrating them by comparatively small reflectors, the small amount of power required, and the fact that—unlike light rays—they pass through smoke and fog without appreciable loss. *Cf.* Esau, Ritz and Beauvais, all in March Abstracts under "Transmission."

Wellen-Induktion in der Drahtlosen Telegraphie (Wave Induction in Wireless Telegraphy).—K. Uller. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 15–22.)

The keynote of the whole paper is expressed by the opening epigram "Wireless waves are wired waves." The writer refuses to consider them as free waves reflected and refracted: they are bound or conducted waves, the conductors being surfaces of discontinuity. "The production of conducted waves is named wave-induction: direct, when the source lies in a discontinuity surface; indirect, when it lies outside the surface and the emitted wave, by its 'special incidence,'* is partly or wholly converted into a conducted wave." Elastic round-the-earth waves have long been known as earthquake phenomena: the analogous wireless return waves have only recently been recognised.

Conducted waves travel either on the surface of one medium or on both sides of the surfaces of separation of two different media or two similar media in relative motion. These surfaces impress a definite velocity and damping on the conducted waves. The general theory of these waves has never yet been recognised, owing to lack of knowledge of the writer's universal wave-theory, which he calls the Interference Principle (published 1917). For twenty years he has published paper after paper expounding the principles of the nature and origin of these waves, and apparently no one has understood him. The present paper, in its mathematical treatment of conducted waves, obtains as the "Condition for Induction" the equation $a_{e2}\sqrt{a^2_{e1}} + a_{r1}\sqrt{a^2_{e2}} = 0$. Direct induction is always possible; indirect, only when this condition is fulfilled. The waves must be complex: in general, a wave has a duality of wave-surfaces—that of phase and that of damping—which can cut each other at any angle. The writer explains Fading as a result of wave-induction, and points out the fallacy of attributing the velocity of Light to the round-the-earth waves in order to derive the length of path and—from this—the height of the Heaviside layer.

* *i.e.*, where $N = 0$, N being the function of the diffraction index in the equation $A_d = \frac{Z_d}{N} \cdot A_a$.

FADING CURVES AND WEATHER CONDITIONS.—R. C. Colwell. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 143–148.)

An extension of the paper referred to in Abstracts, February, describing and illustrating the sunset fading curves at Morgantown from KDKA, which is approximately on the same meridian. The curves taken on fine days show more irregularity during the daylight hours than those taken on cloudy days. It was found that the strength of signals during the dark hours sometimes fell far below the daylight strength. Observations made in the very static-free summer of 1928 showed that the weather conditions had such a decided effect on the signal strength that it was possible to foretell the weather one day ahead by the form of the fading curves. If the curve continued to rise after sunset, a wet or cloudy day followed; if the curve fell, the weather tended to clear.

EFFET D'UN CHAMP MAGNÉTIQUE SUR DES PHÉNOMÈNES DE RÉSONANCE DANS LES GAZ IONISÉS (Effect of a Magnetic Field on Resonance Phenomena in Ionised Gases).—H. Gutton. (*Comptes Rendus*, 28th January, 1929, V. 188, pp. 385–386.)

Continuing his investigations (Abstracts, March; also 1928, V. 5, p. 222), the writer has tested the effect of a magnetic field on that absorption band in an ionised gas which he explains by assuming that the displacement of an electron creates a restoring force proportional to the displacement. The magnetic field was set at right angles to the direction of the variable H.F. electric field. The results when plotted in a curve show that the absorption band for $i_0 = 1.03$ divides itself, under the influence of the magnetic field, into two bands corresponding to the currents $i_1 = 1.50$ and $i_2 = 0.31$; an effect analogous to the Zeeman effect. The subdivision of the band by a magnetic field confirms the existence of resonances, and the value worked out for the ratio e/m (1.61×10^7 e.m.u., m being the mass and e the charge of the particle involved) shows that the electron is concerned. Tests on 1.804, 2.487 and 4.80 metres give the same result.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

ON THE THEORY OF THE SOLAR DIURNAL VARIATION OF THE EARTH'S MAGNETISM.—S. Chapman. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122A, pp. 369–386.)

Various theories are compared. The "dynamo" theory suggested by Balfour Stewart (attributing the variation "S" to overhead electric currents induced by convective motion of the air across the earth's magnetic field) has held its ground for more than a generation: it gives a good account of the general form of the current system as derived from the author's spherical harmonic analysis of S. When, however, it attempts to explain the phase and intensity of the currents, it is handicapped by our lack of knowledge as to the convective motion which induces the currents, and as to the total conductivity of the layer in which they flow. Schuster and the author—rather differently—have each tried to connect the convective motion at the higher levels with the effects observed in the lower atmosphere: their results agree in making the dynamo theory place the S current foci about 2 to 2¾ hours later than is actually observed. This discrepancy is about twice as great as that given by the "drift-current" theory (see later) or by Gunn's diamagnetic theory (Abstracts, 1928, V. 5, p. 578), but this objection to the dynamo theory would vanish if an inversion or large change of phase could be shown to exist for the upper atmosphere diurnal convection.

The only objection then remaining against the dynamo theory would be that it demands a total electrical conductivity of the current-layer of the order of 10^{-5} e.m.u. — 20 times as great as Pedersen's estimate. The writer shows, however, that this estimate could well be quadrupled by correcting certain assumptions made by Pedersen (*e.g.*, $T = 220$ deg. at all heights in the stratosphere, and that mixing by convection ceases at 12 km.). If the dynamo theory by itself is to be accepted, this quadrupling would not be enough and still higher conductivity would have to be proved. On the other hand, if the "dynamo" and the "drift current theory" (which gives, as a main cause for S, the drift motion—always eastward—of the free charges under the influence of the earth's magnetic field) are combined as joint causes of S, they would account satisfactorily for all the phenomena, unless the large change of phase (mentioned above) in the diurnal convection in the upper atmosphere is proved to be non-existent. If it exists, the "dynamo" component would account for the phase discrepancy referred to above, which the "drift-current" component could not explain; while the two components would combine to fit in with a conductivity of a reasonable value. The writer's rejection of Gunn's diamagnetic theory is based on his calculation that if the number of diamagnetically effective free charges were large enough to explain S, the drift currents would be great enough to produce a value of S 250 times as intense; "the diamagnetism of the outer atmosphere makes only an insignificant contribution to S." Other interesting points in the paper are: the electrons contribute almost their full quota to the diamagnetism from 90 km. upwards, so that the conducting layer is rendered diamagnetic by the electrons; the ions only begin to contribute fully to the diamagnetism at about 150 km., *near where the conducting layer ceases*: for in a previous section it is shown that the upward extension of the layer is subject to "a hitherto unsuspected limit" depending on the specific conductivity for directions transverse to the magnetic field: the layer must probably lie between 100 and 170 km. height above the ground.

THE DISTRIBUTION IN SPACE OF THE SUNLIT AURORA RAYS.—C. Størmer. (*Nature*, 19th January, 1929, V. 123, pp. 82–83.)

Krogness has suggested that the great heights of these sunlit rays may be due to the sun's radiation pressure pushing away the upper atmosphere tangentially like a small tail of a comet: if the corpuscular rays hit this tail they produce aurora at unusual heights. The writer brings experimental

evidence in support of this theory, based on simultaneous photographs from two stations which fixed the altitude of these rays on two occasions.

THE TIME INTERVAL BETWEEN MAGNETIC DISTURBANCE AND THE ASSOCIATED SUNSPOT CHANGES.—J. M. Stagg. (*Geophys. Memoirs*, No. 2, 1928, V. 5, 16 pp.)

A correlation of observations over thirty-five years at Kew and Greenwich shows, in agreement with Maurain (Abstracts, 1929, V. 6, p. 41), that the greatest sunspot-area-number occurs about $2\frac{3}{4}$ days before the maximum magnetic disturbance on the earth. The author, however, suggests that for studying the length of time between the emission of the solar particles and their arrival at the earth, the day-by-day fluctuations of sunspot-numbers have more to say than the sunspot-numbers themselves—since the emission is thrown out presumably during the development of the spot rather than at the stationary point of greatest extension. Various groups of years and various ways of averaging show that the sunspot areas increase most rapidly from the (n-5) to the (n-4) day, *i.e.*, round about the fourth day before the maximum magnetic disturbance. In years of slight sunspot activity, the greatest area-increase occurs perhaps a day earlier, but is less marked. The writer considers the four days to be, not the actual time of passage of the particles, but the upper limit of this: for the letting loose of a magnetic storm depends also on the state of ionisation of the upper atmosphere and occasionally will only take place after a number of small impulses.

DIE HÄUFIGKEIT (MITTLERE DAUER) APERIODISCHER WELLEN DES LUFTDRUCKES UND DER TEMPERATUR (The Frequency—mean Duration—of the Aperiodic Waves of Atmospheric Pressure and Temperature).—F. Travniček. (*Met. Zeitschr.*, No. 7, 1928, V. 45, pp. 241–251.)

The pressure-wave frequency all over the world lies between the comparatively narrow limits of 115 and 71 per year. The temperature-wave frequency is even more uniform—between 113 and 92. Many other details are given.

HIGH-VOLTAGE PHENOMENA IN THUNDERSTORMS.—M. A. Lissman. (*Journ. Am. I.E.E.*, January, 1929, V. 48, pp. 45–49.)

Lightning phenomena are analysed in the light of laboratory experience with high-voltage phenomena in the atmosphere. Special emphasis is placed on the effect of space charges in producing high local stresses when they are "mobilised" through channels of high conductivity ("filaments") caused by high temperatures.

LIGHTNING AND OVERHEAD ELECTRIC POWER LINES.—E. Beck. (Summarised in *Nature*, 19th January, 1929, V. 123, p. 109.)

The article describes the apparatus and methods used by the Westinghouse Company in investigating the exact nature of the disturbance caused by a lightning flash in the immediate neighbourhood of an overhead line. The position of the lightning stroke is located by an instrument called the "osiso" which accurately measures the time between the beginning of the oscillograph transient and the arrival of the noise of the thunder. A photographic film speed of 12,000 ft. per minute is only suitable for recording (by Dufour Oscillograph) slow lightning transients; to record the more rapid effects, a quick oscillatory motion is given to the electron beam.

PROPERTIES OF CIRCUITS.

ON THE VARIATION OF GENERATED FREQUENCY OF A TRIODE OSCILLATOR DUE TO CHANGES IN FILAMENT CURRENT, GRID VOLTAGE, PLATE VOLTAGE, OR EXTERNAL RESISTANCE.—K. B. Eller. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1706–1728.)

Author's summary: "The general expressions for the generated frequency of the grid-tuned and the plate-tuned oscillators are developed. In developing these expressions it is assumed that the grid takes a convection current and that there are external resistances in the circuits. The equations which represent the frequency of oscillation of the two types of oscillators are similar and indicate that in order to transform from one type of generator to the other it is only necessary to interchange the plate-circuit constants with the grid-circuit constants.

"The effect of making any change in the circuit conditions which causes the grid current to increase is observed to cause the frequency of oscillation to decrease; and likewise any change which does not affect the grid current does not affect the frequency.

"For fixed grid-battery voltage and plate-battery voltage the effect of decreasing the filament current below its rated value is to increase the generated frequency for both types of oscillators. This change in frequency is greatest for positive values of grid-battery voltage and low plate-battery voltage. With fixed filament current and plate-battery voltage, the effect of changing the grid-battery voltage from negative to positive values is to cause at first a decrease and then an increase in the generated frequency. This change in frequency is greatest for low plate-battery voltages and high (near rated) filament currents.

"For fixed filament current and grid-battery voltage the effect of increasing the plate-battery voltage is first to lower the generated frequency and then to raise it.

"For both types of oscillators, the effect of inserting a resistance (0 to 600 ohms) in series with the condenser is to increase the generated frequency for all values of E_c, E_b and I_f. The presence of this resistance does not greatly affect the shape of the frequency-grid voltage curves. For low values of plate-battery voltage the effect of a resistance in series with the tuned coil is to cause the frequency of oscillations to increase for both types of oscillators. However, for high values of plate-battery voltage the effect of this resistance is opposite for the two oscillators. For high E_b the effect of increasing the resistance in the inductance branch is to decrease the frequency in the case of a grid-tuned oscillator and to increase the frequency in the case of a plate-tuned oscillator. The equations developed

in this paper indicate that the grid current is responsible for the decrease in frequency with increase of the resistance in the inductance branch in the case of a grid-tuned oscillator with high plate voltage.

"For both types of oscillators, the effect of inserting a resistance in series with the tuned circuit as a whole is observed to cause the frequency at first to increase rapidly and then to become constant. For high values of this resistance (10,000 ohms) the frequency of oscillation is practically independent of grid voltage and particularly so for high plate voltage. For low values of plate-battery voltage the effect of a resistance in series with the exciting or tickler coil is to cause the frequency to increase rapidly for values of this resistance less than about 10,000 ohms and to cause only a slight further increase in frequency for values of resistance greater than 10,000 ohms. However, for high values of plate-battery voltage the effect of a resistance in series with the tickler coil is to decrease at first the frequency and then to increase it. The effect of this resistance is in general the same for both types of oscillators. The frequency variation is greatest for positive values of grid-battery voltage.

"The grid-tuned generator will oscillate over a much wider range of variables than will the plate-tuned oscillator and frequency variation for the same change in circuit conditions will in general be less for the grid-tuned than for the plate-tuned oscillator.

"The above discussion applies to oscillators without a grid-leak and grid condenser.

"With properly selected values of grid-leak resistance and grid capacity both the grid-tuned and the plate-tuned oscillators may be made to generate a frequency which is very nearly that given by the equation $f = \frac{1}{2\pi\sqrt{LC}}$ for relatively large changes in E_c, E_b and I_f. In this work, by using a grid capacity of 0.025 μF. and a grid leak of 0.5 megohm the frequency variations were about 0.1 per cent. for a 60 per cent. change in plate-battery voltage and 0.08 per cent. for a 30 per cent. change in filament current for the grid-tuned oscillator. For the plate-tuned oscillator the frequency variations were 0.087 per cent. and 0.027 per cent. for 60 per cent. change in E_b and 30 per cent. change in I_f, respectively. These figures represent experimental results obtained near 1,000 cycles per second. The theoretical equations developed seem to explain all of the experimental curves obtained.

"The results of this work indicate that with the given methods of operation, and by holding the values of the grid voltage, plate voltage and filament current constant within practical limits, the plate-tuned oscillator can readily be made to generate a frequency constant to one part in 20,000. By more refined precautions the constancy can be made still greater."

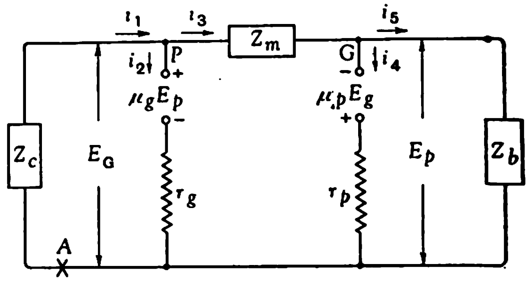
EFFECT OF ANODE-GRID CAPACITY IN ANODE-BEND RECTIFIERS: PART I.—E. A. Biedermann. (*E.W. & W.E.*, February, 1929, V. 6, pp. 71–76.)

The writer rejects Medlam's analysis (*ibid.*, October, 1928), which led to the conclusion that the reaction due to anode-grid capacity causes considerable distortion, and proceeds to outline (using impedance operators) what he believes to be the correct theory. At the end of this first part he sums up: "Thus, in so far as the feed-back causes an increase of the effective resistance of the input circuit, it decreases any distortion which may arise from phase shift of the side-bands, of which phase shift there is always a certain amount present."

There is a correspondence on this subject in the same journal, pp. 93–95, where Medlam defends his methods and mentions experimental results which led him to the theoretical investigation.

THE CONDITION OF SELF-OSCILLATION OF A GENERAL TRIODE SYSTEM.—P. S. Bauer. (*Proc. Nat. Acad. Sci.*, January, 1929, V. 15, pp. 25–29.)

Miller and Chaffee have shown that under the hypotheses of the equivalent plate and grid circuit theorems for voltages and currents of small amplitudes, the general equivalent circuit of a valve is that shown in the figure, where Z_c, Z_m and Z_b are the grid-circuit, mutual-circuit and plate-circuit complex impedances, and μ_p, μ_g, r_p and r_g are the usual valve parameters, assumed to be constant.



The present paper develops the general relations, between the circuit parameters, which cause the condition of self-oscillation. Two theorems are established, the second following from the first: "the self-oscillatory relation between the circuit parameters is invariant of the point of application of the applied voltage": and "a necessary and sufficient condition for self-oscillation is that the determinant of the coefficients of the equations of the currents in the system is equal to zero."

From these theorems it is shown that the condition for self-oscillation is:—

$$\Delta = Z_b Z_c[\{r_p(\mu_g - 1) - r_g(\mu_p + 1)\} - Z_m(\mu_g \mu_p + 1)] - Z_m(Z_c r_p + Z_b r_g) - r_p r_g(Z_b + Z_c + Z_m) = 0$$

The significance of the variables in this equation, and the method of using it to determine the frequency of self-oscillation and the relation between the inductances, capacitances, and resistances, are then explained.

SUR LES OSCILLATIONS D'ORDRE SUPÉRIEUR D'UN CIRCUIT OSCILLANT (The Higher Frequencies of an Oscillating Circuit).—Chenot. (*Journ. d. Phys. et le Rad.*, No. 5, 1928, V. 9, pp 74 and 75.)

Tests, on parallel wires bridged at one end by a

copper plate and connected at the other end each to a small electrometer condenser, showed that Rayleigh's formula for the partial frequencies of a string of length L and thickness d, fixed at one end and weighted at the other with a mass M, holds also for the resonance frequencies in the electrical analogy; L now representing the length of the wires, M and d the capacities of the end condensers and of the wires per centimetre. The equation is

$$\text{Cot}\,\frac{2\pi L}{\lambda} = \frac{2\pi}{\lambda}\cdot\frac{M}{d}$$

DER PARALLELKONDENSATOR IN FREQUENZVERVIELFACHUNGS-SCHALTUNGEN (The Parallel Condenser in Frequency-multiplying Circuits).—Gg. Hilpert and H. Seydel. (*E.T.Z.*, 31st January, 1929, pp. 149–154.)

In connection with H.F. generators, the method of operation of the "parallel condenser" (in parallel with the iron-core choke) is described, and its optimum value for a given generator calculated. The great improvement which it produces is due to the gradual handing-on of the energy to the secondary circuit, instead of the shock process which takes place if no parallel condenser is present. The ratio L/C can be increased a hundredfold, with a consequent great decrease in damping: the wide wave-band in the aerial shrinks up, leaving only one overtone which is so weak that it can be filtered out. The mathematical treatment is supported by oscillograph curves. The value of the condenser is of the order of 9,000–30,000 cm.

A METHOD OF TREATING RESISTANCE-STABILISED RADIO-FREQUENCY AMPLIFYING CIRCUITS.—B. L. Snavely and J. S. Webb. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 118–126.)

Recently there has been considerable use of tuned radio-frequency amplifying circuits employing a resistance in the grid circuit for the purpose of preventing oscillation. Steady oscillation cannot occur if the value of R exceeds the value of the negative input resistance of the valve. The value of R for which oscillations are just maintained when once started is here termed the critical value. Since the input capacity of the valve is generally not negligible in comparison with the tuned-circuit capacity, any increase of R beyond the critical value causes an effective increase in the resistance of that circuit. It therefore becomes desirable to have some means of calculating the critical value.

An equation is here developed for a resistance-stabilised amplifier having a tuned grid circuit and a pure inductance plate load: it has been necessary to assume at first that no current flows between grid and filament, that the plate-to-filament capacity is negligible, and that the grid-to-filament capacity is zero. Later, the conditions for a plate load of any type are considered, and approximation formula which will take into account the grid-filament capacity. An experimental curve shows the great change of the critical resistance for a small change in this capacity. The great steepness of this curve, combined with the accuracy with which the critical resistance can be determined (within a fraction of 1 per cent.) suggests a method for measuring very small capacities—which could be connected between grid and filament. A variable condenser thus connected would provide a control of regeneration in such a type of circuit—the grid-circuit resistance being kept fixed and the critical value being made to approach this fixed value by varying C_{gf}.

THE THEORY OF OSCILLATIONS AS ALTERED BY RADIO-TELEGRAPHIC DEVELOPMENT.—J. Zenneck. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 90–101: part of a long paper, "The Importance of Radiotelegraphy in Science.")

The old Kirchoff-Kelvin equation: the decay of amplitude in circuit including a spark—linear rather than exponential: the increase of current at closing of arc generator—negative resistance: resonance curve of a valve generator impressed with an E.M.F. of constant amplitude but variable frequency—oscillating audion—another result of a resistance whose sign and value depend on amplitude of current: voltage-current characteristic of circuit containing closed iron core—resonance curves of such a circuit: non-reciprocal inductive coupling between two circuits coupled through a valve: shock excitation by quenched gap, etc.: magnetic synchronised shock excitation: the writer's original frequency-doubling suggestion (non-saturation)—Epstein's frequency-doubler (with saturation): demultiplication: circuit arrangement (generator circuit tightly coupled to circuit containing closed iron core) for producing self-modulated oscillations in primary and secondary currents, contrary to the general assumption that when a generator of constant frequency and amplitude acts upon a system of circuits, the currents in these circuits will have constant amplitude, at any rate after the transient phenomena have disappeared.

TRANSMISSION.

DIE ERZEUGUNG KÜRZESTER ELEKTRISCHER WELLEN MIT ELEKTRONENRÖHREN (The Generation of the Shortest Electric Waves by Electronic Valves).—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 27–30.)

A survey of results up to date, starting with the damped (spark-produced) half-metre waves of Hertz and the still shorter ones of Righi, Lebedew, Lampa and Möbius; Nichols and Tear obtained a fundamental of 1.8 mm., while Arkadiewa—with his 0.13 mm. wave—invaded the region of long wave heat radiation. All these spark-generated waves are very feeble in energy and their great damping makes them almost useless for dispersion or absorption measurements, etc. The rest of the paper deals with valve methods of production: (1) by reaction methods—Gutton and Touly (1919) 1.5 m.; three-point circuits with parallel wires—Hollmann, 92 cm. continually increasing to 10 m.; Huxford, 1 m.; Bergmann, 82 cm., with considerable energy: balanced or symmetrical two-valve circuits first proposed by Eccles and Jordan; Holborn's push-pull generator, down to 2.4 m.: Hollmann's modification, with cross-connections and inductive reaction—very serviceable for waves of a few metres, or (with special

low-capacity valves) down to 1.7 m.—Bergmann—and 1.5 m.—Mesny; Gutton and Pierret, keeping inductive reaction but not the cross connections, reached 110 cm. Englund, with a special double valve (to cut short the connections) could not get much energy into a 1.05 m. wave. This is apparently the lower limit for symmetrical circuits. For all reaction arrangements, the frequency is limited not only by the increase of current at the expense of alternating voltage at the electrodes (due to changes in the relation C/L) but also by the electron time between electrodes becoming comparable with the length of the period of oscillation. By the equation $t = \sqrt{\dfrac{d}{v \cdot \dfrac{e}{m}}}$, for an anode radius of 0.5 cm. and an anode voltage of 500 v. the electron time works out at 0.7×10^{-9} sec. The half-period of a 1 m. wave is 1.7×10^{-9} sec.; it is comprehensible, therefore, that the 1 m. wave is about the limit. The next part of the paper will deal with the generation of oscillations by influencing the electron motion by control fields.

Recent Developments in Low Power and Broadcasting Transmitters: Discussion. —E. L. Nelson. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1776–1778.)

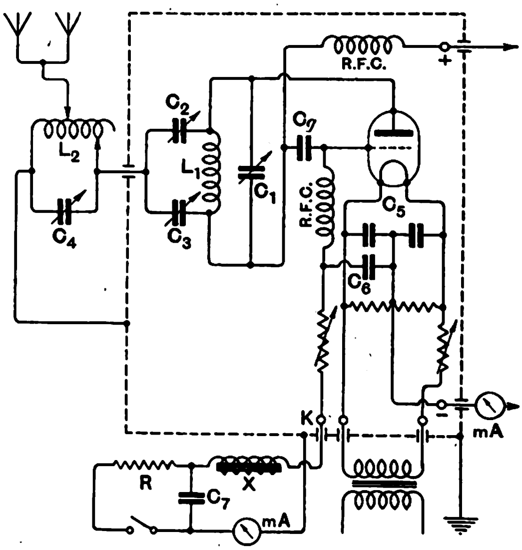
Byrnes, in his paper in the May "Proceedings," discusses the rating of transmitters and stresses the importance of excluding losses in the antenna coils in computing the output power. While agreeing with this, the writer calls attention to a point even more frequently neglected—modulation capability: *i.e.*, the maximum degree of modulation possible without serious distortion, employing a single-frequency sine-wave input and using a rectifier coupled to the antenna in conjunction with an oscillograph or harmonic analyser to indicate the character of the output. There is evidence to show that the average modulation capability of American broadcasting stations is not greater than 50 per cent. (But *cf. G.E. Rev.*, under "Stations.") "Having in mind that beat-note interference and power limitation are the most serious problems that confront the broadcasting industry to-day, it is of interest to note that . . . the same signal-to-noise ratio could be produced by stations of one-fourth the carrier power output provided their modulation capabilities were doubled, that is, made to approach 100 per cent." He then discusses the difficulties in obtaining 100 per cent. modulation of high quality, mentioning the condition, with the Heising system "now generally employed," for complete modulation—that the peak value of the alternating voltage superimposed upon the direct plate voltage impressed on the oscillator or modulated amplifier shall be equal to the direct voltage. The obvious way to make this possible is to supply the modulator valves with a higher anode voltage than is used for the radio-frequency valves; and since the power in a completely modulated wave is 50 per cent. greater than that represented by the unmodulated carrier, and this extra power must be supplied by the modulator, the ratio of modulator power to oscillator power might well have to be as much as 3 or 5 to 1. "These conditions favour that type of system in which the modulation is effected at low power levels and the requisite power output obtained by subsequent power stages amplifying modulated radio-frequency power."

Modulation Methods.—(*German Patents*, 465,501, Lorenz, and 467,022, Könemann, pub. September and October, 1928.)

The first patent states that in long-wave telephony the whole frequency band to be transmitted is so broad, compared with the carrier frequency, that the side-band frequencies are considerably weakened in the aerial circuit with the resonance-curves as actually used. Broadening these curves has the disadvantage of bringing out harmonics and side-waves. It is here proposed to produce the carrier wave in a lightly damped circuit and then to apply the modulation in an oscillatory system with a broad resonance curve. In the diagram the aerial circuit consists of a two-wave circuit (into which the carrier wave is induced) out of which emerge the aerial and the earth lead, in the latter of which the modulating arrangement is found. In the second patent, a rejector circuit in the aerial has its wavelength modified by the modulation current (*e.g.*, by having its inductance formed by the secondary winding of a microphone transformer).

A Poor Man's M.O.P.A.—J. T. McCormick. (*QST*, January, 1929, V. 13, pp. 25–28, 78.)

Description of the reasoning-out and construction of a 3,500/7,500 kc. telegraph transmitter, one



valve (self-excited oscillator), to give a constant note comparable with that given by a crystal-controlled set. Starting from the fact that the oscillations of a *receiver* can be kept reasonably constant, it is shown that this is because, compared with a usual transmitter, the valve runs perfectly cool and there is very little load on the control

circuit. Applying these facts to a transmitter, the writer obtains the circuit shown in the diagram, which he finds very satisfactory.

On the Determination of the Optimum Radiation Angle for Horizontal Antennas.—A. Meissner and H. Rothe. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 35–41.)

A paper on the Berlin to Buenos Aires tests (Abstracts, 1928, V. 5, p. 637). They were made between 11 a.m. and noon and between 6 and 9 p.m., in winter. Reception tests on the same aerial systems showed that no marked improvement could be obtained by using a receiving system inclined to the horizontal: but these tests were limited, being possible only in the morning owing to local reasons. As regards transmission, the writer suggests that the angle 0 deg. is so particularly favourable (but *cf.* Hendricks, March Abstracts under "Aerials") because the very dispersed radiation of the reflector (as shown by the polar diagram) may be concentrated more strongly by the reflecting influence of the earth: in the emission of horizontally polarised waves the influence of the earth on the upward bending of the rays is apt to be very great.

RECEPTION.

Das Problem der Ökonomischten Vielfachtransponierung (The Problem of the most economic Multiple Frequency-Changing Reception).—F. Aigner. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 9–15.)

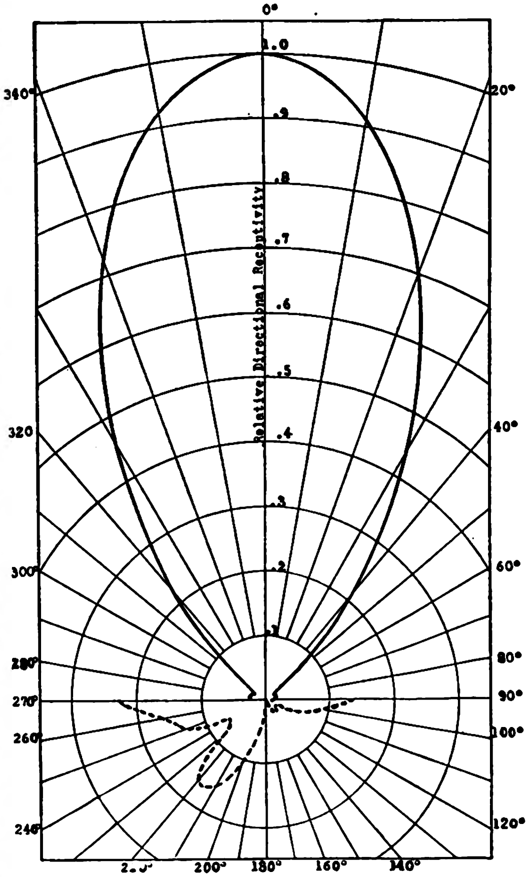
The paper begins by a comparison between Neutrodyne and Frequency-Changing methods. It mentions "an erroneous idea" that a superheterodyne is, on theoretical grounds, more selective than a neutrodyne, and shows that no such superiority exists in theory. On practical grounds, however, the frequency-changing method has the advantage, and the writer's first object is to put this on the most economic basis by reducing to a minimum the number of fixed local oscillators. His second object (dealt with in the part of his paper still to appear) is to develop apparatus, for un-modulated and modulated waves, which shall retain all the advantages of the method and possess as well advantages attainable with no existent apparatus—particularly with regard to sharpness of separation. The present paper deals with apparatus with normal selectivity; only two local oscillators, or one yielding two harmonics, are found to be necessary; or one oscillator giving a fundamental and harmonics can, by a combination of difference frequencies with these harmonics, yield a whole series of suitable oscillations.

Aperiodic H.F. Amplification with Modern Valves.—F.L.D. (*Wireless World*, 13th February, 1929, V. 24, pp. 173–174.)

Suggestions for the application of recent developments in valve and H.F. choke design. Attempts at aperiodic H.F. amplification with H.F. choke coupling have hitherto met with small success for waves much less than 1,000 m. The advent of such valves as the P.M.4DX, with a rated amplification factor of 15 and an A.C. resistance as low as 7,500 ohms, and the general improvement in the characteristics of commercial H.F. chokes, make it worth while to reconsider this method of amplification; particularly as a preliminary stage in superheterodyne or portable receivers.

The Receiving System for Long-Wave Transatlantic Radio Telephony.—A. Bailey, S. W. Dean and W. T. Wintringham. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1645–1705.)

Authors' summary: "Transmission considerations and practical limitations indicate that in the lower frequency range, frequencies near 60 kc.



Wave-Antenna Array Directional Characteristic. Calculated Relative Directional Receptivity of Array of 4 Houlton Antennæ. (From Average Measured Unit Antenna Characteristic.) Dotted Curve—Magnified × 10.

are best suited for transatlantic radiotelephone transmission. A radio receiving location in Maine gives a signal-to-noise ratio improvement over a New York location equivalent to increasing the power of the British transmitter about 50 times.

Various types of receiving antennæ are briefly discussed. The wave-antenna is selected as being most suitable for long-wave radio telephony. The various factors affecting wave-antenna performance and methods for measuring the physical constants of wave-antennæ are discussed in detail. High-frequency ground conductivities determined from wave-antennæ measurements are given. Combination of several antennæ to form arrays is found to be a desirable means of decreasing interference. The use of a wave-antenna array in Maine decreases the received noise power by an additional 400 times. If the receiving were to be accomplished near New York using a loop antenna, we would have to increase the power of the British transmitting station 20,000 times to obtain the same signal-to-noise ratio. Comparisons of calculated and observed directional diagrams of wave-antennæ and wave-antenna arrays are presented and discussed.

"The transmission considerations governing the design of a radio receiver for commercial telephone reception are outlined.

"Mathematical discussions of the wave-antenna, antenna arrays, quasi-tilt angle, and probability of simultaneous occurrence of telegraph interference are given in the appendices."

The polar diagram reproduced is considered to represent about the best that can be done economically in a general reduction of back-end area and narrowing of the diagram by means of wave-antennæ.

Neue Empfangsschaltungen mit neuen Mehrfachröhren (New Receiving Circuits with New Multiple Valves).—M. v. Ardenne. (*Rad. f. Alle.*, November, 1928, pp. 488–499.)

The writer and Loewe have designed a new type of double valve for the special purpose of cascade H.F. amplification in the Broadcast band, for distant reception on frames. The writer was led to do this because he finds that—except perhaps in America—a total H.F. amplification up to the maximum 5,000 (which he considers the limit) is hardly ever obtained with ordinary valves (even screen-grid valves) owing to the multiplicity of stages necessary. The new valve has only a single grid, and various changes in the internal structure make it very different from the older H.F. double valve, though its external size, etc., is the same and its amplification equal to or greater than that of the old type. Its frequency-dependence in the Broadcast band is much less—an important advantage. Internal capacities are so reduced that L.F. amplification hardly exists, so that with the circuit which he specifies six H.F. stages are obtainable without trouble. The necessary screening is described. In one arrangement recommended, the connecting wires to the tuned circuits take the form of cable with earthed sheaths. The amplifier also works well as an intermediate frequency amplifier for short-wave reception; the lay-out of a complete scheme for this purpose is given.

Automatische Lautstärkeregelung (Automatic Volume Control).—H. Kröncke. (*Rad. f. Alle*, December, 1928, pp. 529–531.)

After describing the need for automatic control especially for long distance broadcast reception where fading comes in, the writer says that there are signs that in America every broadcast receiver will soon incorporate such a device. He considers the problem on general lines and then concentrates on the Wheeler circuit (Abstracts, 1928, V. 5, pp. 35 and 165) which he estimates as giving (for a three-stage control) a regulation of 1 in 1,000, provided the individual stages are properly neutralised.

Progress in Radio Receiving during 1928.—A. N. Goldsmith. (*Gen. Elec. Review*, January, 1929, V. 32, pp. 74–81.)

Illustrated by photographs of American apparatus. The incorporation of automatic volume control is mentioned (*cf.* Kröncke, above). Photophone apparatus for sound-motion pictures is included. The development of "Centralised Radio" (*e.g.*, for blocks of flats, hotels, etc.) is discussed.

Two-Circuit Two: Selectivity without Loss of Signal Strength.—H. F. Smith. (*Wireless World*, 6th February, 1929, V. 24, pp. 143–148.)

Description of the construction of a two-valve set in which the use of a reacting detector and one stage of L.F. amplification is combined with a tuned aerial circuit auto-coupled with the inductance of the "Hartley" circuit. "Selectivity is, of course, hardly up to the standard of a really first-class set with a single H.F. stage and 'un-tuned' aerial, but it is of a distinctly higher order than that of an indifferent circuit arrangement of this kind, even if matters are not improved in this respect by loosening aerial coupling beyond the point giving loudest signals."

Receiving Sets for Aircraft Beacon and Telephony.—H. Pratt and H. Diamond. (*Bur. of Stds. Journ. of Res.*, October, 1928, V. 1, pp. 543–563.)

Design details for three sets of slightly different types, with numerous characteristic and performance curves, are discussed, with a brief discussion of practical flight tests. The receivers have to be small, light and yet rugged. The tuning system should be of a uni-control type over the whole frequency band 285–350 kc. As the distance is changing so rapidly, a simple volume-control with a uniform action from zero to maximum is necessary. Shielding is necessary to limit ignition interference to that induced in the aerial. The set must be capable of operating a beacon course indicator (see these Abstracts, under "Directional Wireless"): the audio-frequency amplification must be nearly uniform over a frequency range of 40–3,000 cycles (40–120 for the beacon signals and 200–3,000 for good speech intelligibility). Sensitivity (to allow the use of short vertical pole aerials) and selectivity must both be high. These two features, and that of uni-control, are obtained with 3 or 4 tuned radio-frequency circuits with gang variable air condensers. Some regeneration in the detector circuit is provided. Although low-voltage

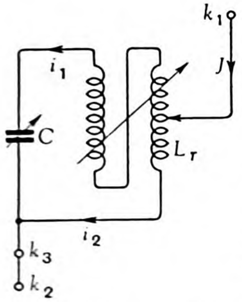
valves would have been welcome, both for their smaller dimensions and for the smaller size of battery, the standard low-voltage valves were found to be not sturdy enough—being often mechanically weak and usually causing microphonic noises. Either special low-voltage valves have to be used, or standard 5-volt valves. "There is much need for better tubes for aircraft sets."

DIE VORRÖHRE BEI TRANSPONIER-EMPFÄNGERN. (The Preliminary Input Valve for Frequency-Change Receivers).—O. Knies. (*Rad., f. Alle*, November, 1928, pp. 503–505.)

Such a preliminary high-frequency stage, in front of the main superheterodyne receiver, not only increases the sensitivity but also prevents re-radiation (which the use of a frame aerial does not avoid entirely). One of the best methods of coupling to the first stage of the receiver is by tuned transformer, auxiliary adjustments being a variable condenser and the grid-bias potentiometer. Other methods are illustrated and discussed.

DER RIEDELSCHE SPERRKREIS (The Riedel Wave-Stopper).—H. Bock. (*Rad. f. Alle*, December, 1928, pp. 541–545.)

The writer has had such good results with this form of rejector circuit that he considers it worth while to investigate it mathematically; this he does here, and then considers some of the practical difficulties; *e.g.*, the difficulty in cutting out harmonics of the local station.



The designer's specification (which the present writer confirms) gives 60 turns to the centre-tapped coil and 50 to the other, both basket-wound (in the same sense) and variably coupled. The finely-adjustable condenser is of the order of 500 cm. The usual precautions against induction into the receiver, and electrostatic action between condenser and coils, are necessary. The connection recommended is k_1 to aerial, k_2 to receiver; k_3 when connected to aerial cuts out the stopper.

EIN 3 M. EMPFANGER: FREQUENZBEREICH N = 94 BIS 111 MILLIONEN (A Receiver for 3 m. Wavelength: Frequency Range 94–111 Millions).—H. Rutenbeck. (*Rad. f. Alle*, November, 1928, pp. 508–509.)

Description with illustrations of an audion receiver with capacity-reaction, specially designed to obtain fine adjustment and smooth reaction.

THE THEORY OF PUSH-PULL: CONSIDERATION OF LOUD SPEAKER WINDINGS FOR OPTIMUM PERFORMANCE.—N. W. McLachlan. (*Wireless World*, 30th January, 1929, V. 24, pp. 114–118.)

AERIALS AND AERIAL SYSTEMS.

THE DESIGN OF TRANSMITTING AERIALS FOR BROADCASTING STATIONS.—P. P. Eckersley, T. L. Eckersley, and H. L. Kirke. (*E.W. & W.E.*, February, 1929, V. 6, pp. 86–92.)

Full illustrated abstract of the paper read before the Wireless Section, I.E.E. "The paper deals with the important technical aspect of the design of the transmitter aerial, and it is suggested that attention to this subject might help to improve broadcasting conditions in Europe generally. Difficulties of mutual interference between stations and of the limited service areas of stations indicate the need for an aerial which produces only a direct or ground ray. The indirect ray interferes with other distant stations, produces fading and bad quality in the local service area. . . ." The authors advocate the use of the highest possible aerials, to give the strongest possible horizontal radiation while diminishing upward radiation; a series of half-wave aerials one above the other, with phasing coils to reverse the phase at each join (Franklin beam aerial), would be best but could hardly be used for waves greater than about 213 m. since mechanical and economic conditions impose a limit of about 800 ft. for the height of masts; but simple half-wave aerials can be used on most [broadcast] wavelengths. If a T aerial is used, the current in the vertical part should be a maximum at the greatest possible height from the earth. Preliminary tests (using a kite balloon) to confirm the theoretical decrease of power to aerial necessary to produce a given field strength, on changing from a quarter-wave to a half-wave aerial, gave good agreement. Unfortunately, only one fading test could be carried out, and this showed less improvement as to fading than was expected. (In the discussion Amis quoted the considerable fading noticed from Germany—the home of the high aerial.) But further investigations under more suitable conditions are to be made. The paper includes sections on Effective Height ("a misleading term for loaded aerials—effective current is more definite," *i.e.*, the average value of the current in the vertical part of the aerial; metre-amperes being found by multiplying the actual height of that part by this average current), and on the Attenuation of Waves.

TRANSMITTING AERIALS.—G.W.O.H. (*E.W. & W.E.*, February, 1929, V. 6, pp. 59–61.)

An Editorial dealing first with Meissner's tests (from Germany to Buenos Aires) on the best inclination to the horizontal for a short-wave beam, and then with the Eckersleys-Kirke paper referred to above. Meissner's second series of tests, on wavelengths 15–20 m., gave signals 5 times as strong when the beam was directed horizontally along the ground as for an angle of 40 deg., and twice as strong as for 10 deg. (see Abstracts, 1928, V. 5, p. 637). This agrees with the Marconi practice of horizontal beam-direction; the apparent paradox, that such horizontal direction is advocated for broadcasting in order to confine the radiation to a limited area round the transmitter, is explained by the difference in behaviour between 15–20 m waves and 200–600 m. waves.

DIE UNHOMOGENE BELASTETE ANTENNE (The Unevenly Loaded Aerial).—A. Witt. (*Journ. Applied Phys., Moscow*, No. 1, 1928, V. 5, pp. 3–21.)

Investigation of the oscillations of an aerial earthed at one end through an inductance: based on the theory developed by Kneser.

INCREASING TRANSMITTING ANTENNA EFFICIENCY.—S. L. Seaton. (*QST*, January, 1929, V. 13, pp. 43–44 and 68.)

Experiments to determine the best type of aerial for a receiver mounted on a truck led to the choice of the resonant wave coil, in preference to short wires, loops, etc. Such a resonant coil was then found very effective (for the space occupied) as a transmitter. Finally, such a coil was added to each end of a half-wave aerial, with good results. A comparison is made to the metal plates of a Hertz oscillator, and the final conclusion is that the addition of a concentrated structure to the ends of an antenna, of a value not exceeding 10 per cent. of the effective capacity or inductance of the antenna itself, may be expected to increase the effectiveness about 14 per cent. provided that the same potential amplitude is assumed in both cases. An end-loading-coil successfully used for a 40 m. wavelength consisted of 22 turns spaced winding of heavy copper on a 2½-inch diam. insulating frame.

BÄUME ALS ANTENNEN FÜR REISE-EMPFÄNGER (Trees as Aerials for Knapsack Receivers).—F. Zolleis. (*Rad. f. Alle*, November, 1928, pp. 522–523.)

Using a tree (non-resinous) as an aerial and its roots as an earth, a screen-grid valve in reaction-audion connection, with another as L.F. amplifier (two flash-lamp batteries providing the anode voltage), will give "distant reception" by day. Connection is made to the tree by two small gimlets penetrating about 10 cm. into the trunk.

ON THE DETERMINATION OF THE OPTIMUM RADIATION ANGLE FOR HORIZONTAL ANTENNÆ.—Meissner and Rothe. (*See* under "Transmission.")

VALVES AND THERMIONICS.

THE MEASUREMENT OF e/m WITH A THREE-ELECTRODE VALVE WITH SIMULTANEOUS MEASUREMENT OF ITS AMPLIFYING FACTOR.—D. S. Kothari. (*Indian Journ. of Phys.*, No. 4, 1928, V. 2, pp. 485–490.)

The method is a modification of Greinacher's, using a valve with cylindrical anode and grid. The lines of force of the electrical field run radially, those of the magnetic field (Helmholtz coil) axially. If a value for e/m is assumed, the amplification factor of the valve can be calculated from the curves plotted.

ALIGNMENT VALVE CHARACTERISTICS.—W. A. Barclay. (*E.W. & W.E.*, February, 1929, V. 6, p. 96.)

A letter referring to Reed's article (*ibid.*, October, 1928): the writer, an enthusiastic advocate of alignment methods, considers that Reed is unduly limiting their scope by applying them to formula-results instead of directly to the original experimental data. *Cf.* Barclay's article, *E.W. & W.E.*, May, 1927.

VALVES WE HAVE TESTED.—(*Wireless World*, 6th February, 1929, V. 24, pp. 156–158.)

Review of the Mazda Series of 4-volt valves.

A SCREEN GRID TRANSMITTING VALVE.—(*Gen. Elec. Review*, January, 1929, V. 32, p. 37.)

Illustration of a 750-watt screen grid power valve specially useful for short wave transmission. On pp. 39 and 40 there is an illustration (and short description) of a 1 kW. transmitter for 15–50 m. wavelengths, with crystal oscillator and three stages of radio amplification, using six four-electrode valves.

NEW GERMAN RECEIVING VALVES.—(*Rad. f. Alle*, December, 1928, pp. 558–560.)

A new Telefunken power valve (RE 604) is mentioned, with an emission of 200 mA. (max. anode voltage 200 v.) and a slope of 3.5 mA./volt. Filament consumption is only a third of that of the RV 218 (whose place it takes for loud speaker purposes) and it is described as "comparatively cheap." The new Te-Ka-De Valves are tabulated on p. 559, full data being given of over 20 types. These include double and triple multiple-valves, and indirect A.C. heated valves.

THE MANUFACTURE OF BARIUM OXIDE FILAMENTS.—B. Hodson, L. S. Hartley and O. S. Pratt. (*Electrician*, 8th February, 1929, V. 102, pp. 160–161.)

Extracts from a paper read before the I.E.E. The only difference between a barium filament and a barium oxide filament is found to be that the former will retain its barium hardly long enough for measurements to be taken. The authors conclude that in a barium oxide filament—*e.g.*, a platinum core coated with the oxide or with the oxide in combination as a platinate—some of the barium oxide is electrolysed and free barium is formed on the surface: the oxide being essential as a support or carrier for the barium, which would otherwise vaporise. Four ways of manufacture are described, several advantages being ascribed to the last of these—the deposition of barium vapour on an oxidised filament (*e.g.*, oxidised tungsten) in vacuo. Curves showing the variation of saturation current with life, for vapour-made filaments and paste-made filaments, show greater constancy of emission and less variation from valve to valve. No comparison, however, is shown between the vapour-made filaments and the filament made by repeated evaporation (in CO_2) of a barium salt solution into which the core wire is dipped 50–100 times. The avoidance of "hot spot" trouble, by making the emitting layer of a composite nature—by the addition of strontium or calcium oxides—and by adopting thin layers, is discussed.

METINGEN OVER DE SOORTELIJKE WARMTE VAN WOLFRAM TUSSCHEN 90 EN 2,600°. ABSOLUUT (Measurement of Specific Heat of Tungsten between 90 deg. and 2,600 deg. K.).—C. Zwikker and G. Schmidt. (*Physica*, No. 9/10, 1928, pp. 329–346.)

New measurements show that above 300 deg., C_p increases linearly with temperature; C_v increases less than linearly and does not exceed 8 cal/gr. atom degree at high temperatures.

OXIDE CATHODES.—(*German Patent*, 467,675, Huth, pub. 26th October, 1928.)

A base fusible with difficulty (tungsten and molybdenum) is mixed in powder form with an oxide or chloride of the 3rd or 9th Mendeléeff's group, and after being pressed into bars is heated up to its own melting point. Strontium or calcium oxide, barium peroxide, palladium chloride, platinum-ammonium chloride, and calcium chloride are specially mentioned.

INCANDESCENT CATHODES. — (*German Patent*, 466,462, Siemens and Halske, pub. 8th October, 1928.)

A coating of hafnium is deposited on a base with high fusing point, by the reduction of a hafnium compound (*e.g.*, hafnium oxide) with the help of an alkali metal.

ELECTRODES.—(*German Patent*, 467,467, Siemens and Halske, pub. 23rd October, 1928.)

To improve the life of strongly heated electrodes, the use of metallic hafnium for the anode is suggested.

ELECTRON EMISSION AT THE SURFACE OF PLATINUM THROUGH WHICH HYDROGEN IS PASSING.—L. T. Jones and V. Duran. (*Phys. Review*, No. 5, 1928, V. 31, p. 916.)

When hydrogen diffuses through the walls of a glowing platinum tube, an electron emission takes place at the emerging surface of the hydrogen which is greatly in excess of the platinum emission at the temperature in question, as given by Richardson. The result is further investigated.

VALVE CURRENT FROM THE MAINS: OBTAINING OPTIMUM PERFORMANCE WITH A.C. VALVES: REMARKABLE CHARACTERISTICS OF THE NEW SCREEN GRID VALVE FOR A.C. MAINS.—E. Y. Robinson. (*Wireless World*, 13th February, 1929, V. 24, pp. 180–184.)

An article based on the new Metropolitan-Vickers valves. These have a non-inductive hairpin-shaped heater coated with porcelain and enclosed in a nickel tube, which itself is coated with a mixture of barium and strontium oxides. "The constituents of the porcelain are such that at the operating temperature of the cathode it is slightly conducting, which is also a factor in preventing mains hum."

CHOOSING THE RIGHT VALVE: THE IMPORTANCE OF SELECTING THE VALVE WITH REFERENCE TO THE COMPONENT IN ITS ANODE CIRCUIT.—A. L. M. Sowerby. (*Wireless World*, 13th February, 1929, V. 24, pp. 168–172.)

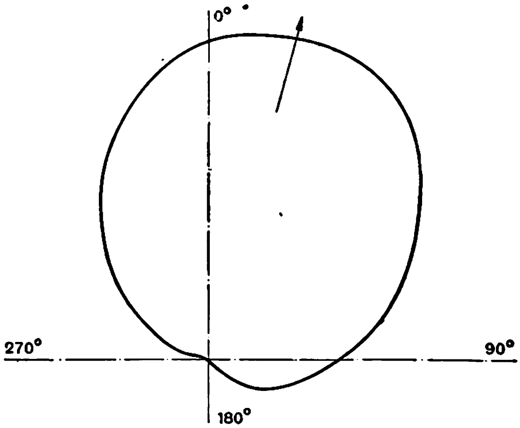
ON GROUPS OF ELECTRONS IN THE GEISSLER DISCHARGE.—K. G. Emeléus and W. L. Brown. (*Phil. Mag.*, January, 1929, V. 7, No. 41, pp. 17–31.)

"Measurements of collector characteristics have been made in the Geissler discharge from a cold cathode in argon, neon, hydrogen, and oxygen, at pressures of about 0.1 cm. Hg., for conditions not far from those at normal cathode fall of potential, from which it is concluded that there is present in the negative glow, and at the low pressures, in the Faraday dark space, a group of fast electrons with a distribution of velocities that is approximately Maxwellian, and an average energy of the order of 25 electron-volts. It is suggested that they are produced initially by electrons passing into the negative glow from the cathode dark space, and that they are maintained by a process which is the reverse of ionisation by collision. A possible effect of the Ramsauer minimum of the free paths of electrons is pointed out, in the persistence of two groups of slow electrons in the discharge."

DIRECTIONAL WIRELESS.

UNIDIRECTIONAL RADIOBEACON FOR AIRCRAFT.—E. Z. Stowell. (*Bur. of Stds. Journ. of Res.*, December, 1928, V. 1, pp. 1011–1022.)

During the development by the Bureau of a directive beacon for guiding aircraft (Abstracts, 1928, V. 5, pp. 463, 466, 521, 582) it appeared that its usefulness could be increased by making the radiated field unidirectional. This paper describes the gradual evolution of an arrangement giving a polar characteristic which is, it is believed, "about



the optimum for aircraft use." Starting with a modified Bellini-Tosi loops-and-vertical wire system, the vertical wire was replaced by using the loops (closed at the top) as the non-directive aerial, by earthing (through a variometer) their common mid-point. The disappointing result was found to be due to the transfer of power to the non-directive circuit being chiefly capacitively through the transformer; so that instead of the non-directive field being in phase with the directive,

it was nearly 90 deg. ahead. A delay circuit improved the diagram but not enough, back radiation still being excessive. Finally, the power for the non-directive field was obtained from an auxiliary goniometer whose primary windings (at 90 deg.) were in series with the primaries of the direction-controlling goniometer; both goniometers were wound so as to minimise capacity transfer between windings. The phase of the non-directive field was controllable by the variometer, and its amplitude by change of the primary turns of the goniometer. By independent adjustment of these two factors, the best result was attained; this was with the non-directive field 55 deg. ahead of the directive field.

In the figure, the arrow represents the angular position of the centre of the equi-signal zone. There is only one radiated course and this occurs practically at the maximum of the field. The diagrams resulting from the non-directive field being 55 deg. behind the directive, or at some intermediate value, are inferior in various ways.

DESIGN OF TUNED REED COURSE INDICATORS FOR AIRCRAFT RADIOBEACON.—F. W. Dunmore. (*Bur. of Stds. Jours. of Res.*, November, 1928, V. 1, pp. 751–769.)

This paper describes the development of the reed indicators mentioned in Abstracts 1928, V. 5, p. 582, with special reference to the choice of the modulation frequencies. The frequencies finally adopted were 60 and 85 p.p.s., which were found very satisfactory both from the beacon point of view and from that of the tuned reed operation. The type *F* indicator finally evolved uses polarised, rear-drive reeds. The polarisation (by permanent magnets) greatly increases the sensitivity: it was made possible by constructing the reeds of steel, instead of the temperature-constant but non-magnetic elinvar, and arranging for automatic temperature compensation by a small bi-metallic strip soldered to the free end of the reed. As the temperature increases this strip bends towards the fixed end of the reed and compensates for the change in Young's modulus. Used with a 6-valve receiving set in the tail of the aeroplane, these indicators work well even when ignition interference makes aural reception almost impossible. Their note selectivity also prevents them from being interfered with by other stations, such as the marine beacons, which work on 1,000 p.p.s. modulation.

ABHÄNGIGKEIT DER FUNKBESCHICKUNG VON METEOROLOGISCHEN EINFLÜSSEN (The Dependence of Wireless Transmission on Meteorological Influences).—P. Duckert. (*Mitteil. Aeron. Obs. Lindenberg*, May, 1928, pp. 154–160.)

More of the author's work on this correlation (*cf.* Abstracts, 1929, V. 6, p. 106). On his D-F results at Nordholz, Borkum and List, he points out that within any one weather-period the bearings vary from the mean value for that period only by a small amount of the order of the observation-error of the apparatus. He suggests that the accuracy of D-F would be increased by a plotting of the results for each main type of weather.

DETERMINATION OF THE INCLINATION OF AIRCRAFT.—(*German Patent*, 465,502, Dieckmann and Hell, pub. 21st September, 1928.)

The voltage induced in a dipole by a distant station is proportional to the dipole length multiplied by the sine of the dip-angle between dipole and the horizontal plane. This fact is here applied to aircraft. Two dipoles can be fitted, one longitudinally and one transversely.

ACOUSTICS AND AUDIO-FREQUENCIES.

ACOUSTIC PHOTOGRAPHS BY THE SHOCK TEST AND TONE TEST.—J. Zenneck. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 107–112; being part of a Paper entitled, "The Importance of Radiotelegraphy in Science.")

The shock test is carried out by a shot from a small 22-calibre pistol, the time curve of the air pressure at some point in the room being registered by means of a Reiss microphone, a multi-stage amplifier with resistance-capacity coupling, and a Siemens oscillograph. This method has the power—owing perhaps to the directive property of the pistol shot—to place with great exactness that portion of a room in which a reflection takes place and which may be the source of a disturbing echo. It is so reliable that, in a case mentioned, results conflicting with the official plan of the auditorium under test led to the discovery that this plan was incorrect. The tone test uses an audio-frequency valve generator and loud speaker, in conjunction with a rotary interrupter: the time curve here also being oscillographed. The two tests work in together: the tone test gives a picture of the result, and the shock test investigates the sources.

PRESSURE DISTRIBUTION IN A FLUID DUE TO THE AXIAL VIBRATION OF A RIGID DISC.—N. W. McLachlan. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 604–609.)

There is a distinct change in the quality of reproduced music according as one stands in front of, or at the side of, a loud speaker. This is due to non-uniform pressure distribution from the diaphragm at various frequencies. When the wavelength of sound is comparable with the radius of the diaphragm there is a focusing effect. This occurs at the higher audio-frequencies and upsets the tonal balance unless the listener is situated on the axial line of the diaphragm. The writer examines analytically the pressure distribution in the space surrounding a flat rigid disc vibrating in a plane of infinite extent, so that there is no interference between the waves emitted by the two sides of the disc. He then gives polar curves of pressure distribution of discs 5 and 10 cm. in diameter at frequencies corresponding to the pianoforte middle (256 p.p.s.; polar curve a semi-circle in both cases) and top (4,096 p.p.s.; polar curve for 10 cm. disc is only about half the width of that for 5 cm. disc, and in area is only about one-ninth of the semi-circle). For uniform pressure distribution over a hemispherical surface, the disc ought to approximate to a point source, though this is impracticable owing to limitations imposed by the driving agent and due to the relatively large amplitudes required to radiate the lower frequencies.

SOUND MEASUREMENTS AND LOUD SPEAKER CHARACTERISTICS.—I. Wolff. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1729–1741.)

Author's summary : " A brief description of the method used to measure loud-speaker response is given. The Rayleigh disc and condenser microphone are compared as sound detectors. A number of loud-speaker sound pressure response curves are shown, and interpreted in terms of pleasantness of reproduction, as determined by low- and high-frequency cut-off, smoothness of response, and tone balance. Tube overloading and the effect of loud-speaker response on its apparent accentuation or diminution is discussed. The effect of room absorption characteristics, room resonances, position of the loud speaker in the room, and position of the listener with respect to loud speaker on loud-speaker reproduction is explained by means of diagrams and loud-speaker response curves."

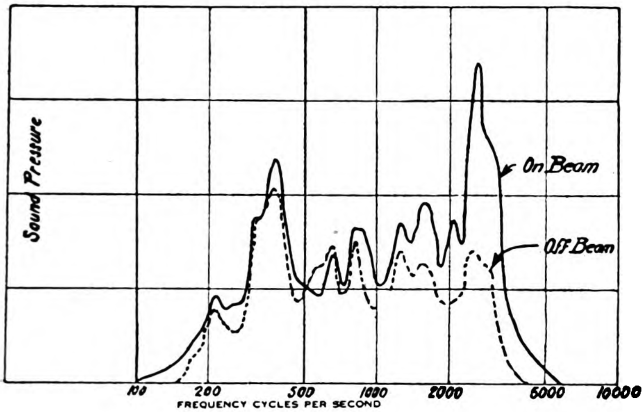


Fig. 1.

Fig. 1 illustrates the effect on the higher frequencies of listening directly in front of the loud speaker. Fig. 2 gives one particular example of cavity resonance (*e.g.*, loud speaker placed in a corner of a room), the effect of which may be pleasing or otherwise, according as the resonance is or is not of such a frequency as to supply a region which is lacking.

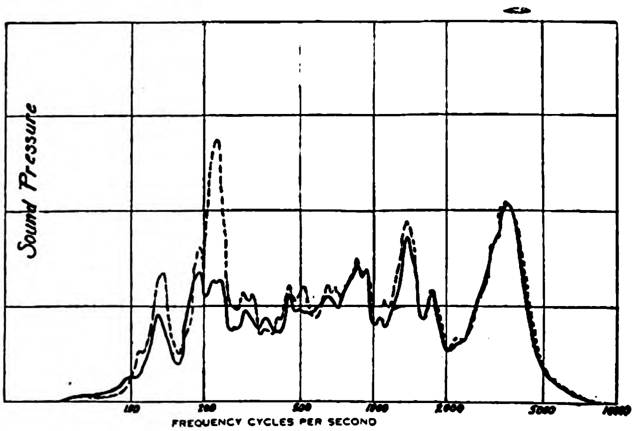


Fig. 2.

AN APPARATUS FOR THE PROJECTION OF FREQUENCY-OUTPUT CHARACTERISTICS.—C. G. Garton and G. S. Lucas. (*E.W. & W.E.* February, 1929, V. 6, pp. 62–70.)

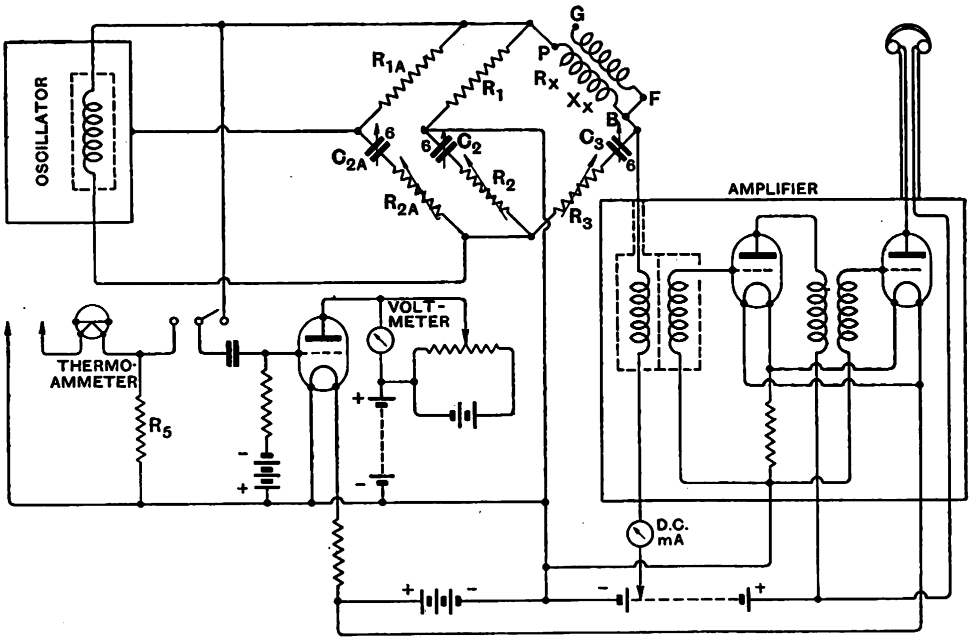
The curve connecting the frequency of input power and the amplitude of the resultant output (for amplifiers, intervalve transformers, loud speakers, etc.) is thrown on a screen ; a rapid non-permanent indication is thus obtained, making it possible for the experimenter to see quickly the results of any change made in the apparatus under investigation. The basic idea of the apparatus is the same as that of Cohen, Aldridge and West (*Journ. I.E.E.*, October, 1926), but the latter method was photographic only. In the present apparatus the horizontal frequency scale is given by reflection of the galvanometer beam at a mirror (rotating about a vertical axis) mechanically coupled to the frequency-changing condenser. No rectification of the output is necessary owing to the use of a special form of hot wire galvanometer, a fine tungsten filament controlling the rotation (about a horizontal axis) of a small galvanometer mirror, and thus providing the vertical " output " scale. The constant-voltage generator of variable frequency is a heterodyne combination, a special filter circuit being used to keep out the unwanted radio-frequency components. For obtaining loud-speaker characteristics, a calibrated condenser microphone is employed, with a linear characteristic amplifier (resistance-capacity) using a screen-grid valve in the first stage. " Although the use of this type of valve for audio-frequency amplification is not yet common, very satisfactory results are obtainable where a high voltage amplification is desired, and when adequate plate voltage is available. With the values given . . . a 'step-up' of about 50 to 1 on the first stage is obtained." Details are given of the apparatus and methods, which were developed at the B.T.H. laboratories and were demonstrated at the recent Physical Society's Exhibition in London.

The Design of Transformers for Audio-frequency Amplifiers with Pre-assigned Characteristics.—G. Koehler. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1742–1770.)

Author's summary: " The requirements of an ideal transformer are stated, and the difficulties encountered in attempting to build transformers for interstage coupling units which will meet these requirements are pointed out. The aim in design for audio amplifiers is stated to be a reasonable voltage amplification for one tube and one transformer which is independent of the frequency over a range necessary for broadcast reception.

" The equivalent A.C. circuit for some types of transformers with tube source and tube load is set up and solved. The impedance and voltage amplification characteristics are explained from the solution of the equivalent circuit. Expressions for calculating the constants of the transformer are given. A study of the design relations and voltage amplification characteristics reveals difficulties which are encountered in design and some methods for overcoming these difficulties. The effect of the continuous flux in the core of the transformer is illustrated and a scheme is given for balancing out the continuous flux.

" A rather universal type of bridge for making the necessary impedance measurements in connection with transformer studies is shown. This bridge is adapted to measuring iron core coils, which carry both alternating and continuous currents, when either inductive or capacitative reactive." See diagram: the scheme has been so worked out that the bridge can be balanced without disturbing the D.C. through the transformer. The D.C. is measured by means of an ammeter in the balance indicator circuit. The A.C. voltage across the transformer is measured by a detector voltmeter across the bridge arm which is adjacent to the transformer. This voltmeter should not be left on when the final balance is made. The purpose of the auxiliary, or guard, arm is to bring the oscillator shield to the same potential as the amplifier shield and detector voltmeter. It must, to be effective, be balanced at the same time that the main bridge is balanced: roughly by making the values of its components equal to the corresponding values in the main bridge, or more accurately by actual balancing if greater precision is needed. *Cf.* Landon, under " Measurements and Standards."



Über die Wirkungsweise des Kathodophons (The Method of Action of the Kathodophone).—E. Meyer. (*E.N.T.*, January, 1929, V. 6, pp. 17–21.)

The kathodophon is used in one system of talking films and has also been employed as pick-up transmitter in German broadcasting. A hot cathode (oxide coated, heated internally by a platinum spiral) is fixed close to a perforated anode, which forms the small end of a mouthpiece or horn. The direction of flow of current from cathode to anode corresponds with the direction of the sound: how exactly the latter affects the ionised gap is not yet understood, but it causes current fluctuations which are led through a high ohmic resistance to an amplifier. The present paper describes an investigation into the behaviour of a simpler form of apparatus working on the same lines. Results show that the action is a motion-effect, the resulting

E.M.F. being proportional to the elongation (of path ?) of the air particles : the effect is greatest at a velocity antinode of a stationary wave, but even here it depends on sound wave and ion directions agreeing.

THE USE OF THE ELECTRET IN A CONDENSER TRANSMITTER.—S. Nishikawa and D. Nukiyama. (*Proc. Imp. Acad. Tokyo*, No. 6, 1928, V. 4, pp. 290–291.)

Euguchi's electret is here used for maintaining the electrical field of a condenser microphone or telephone. In conjunction with a three-cascade amplifier, a better result was obtained than that given by a condenser microphone with battery.

DAS " RADIOPHON " (The Radiophon).—G. Eichhorn. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 30–33.)

A new way of communicating to the auditory centre the output currents of a valve receiver, chiefly to enable deaf people to hear broadcast programmes. The instrument comprises a handle with a contact putting the listener's body in connection with one of the amplifier output terminals, and a diaphragm made of some semi-conductor (cellophane appears to be one of the best) which is metallised on one side—the side away from the listener. This metal film is connected to the second amplifier output terminal, and the non-metallised side of the diaphragm is pressed against the ear or some part of the head near the organs of hearing. A high resistance (about 100,000 ohms) contained in the handle is shunted across the two electrodes (the handle contact and the metallised diaphragm) and allows the D.C. component of the output current to pass. The D.C. voltage has an important action in the process : if the A.C. voltage is small, the optimum D.C. voltage is about 120–150 v. ; if the A.C. voltage is larger, the D.C. voltage can be decreased considerably. A deaf person whose tympanum does not function can hear well with this apparatus, provided that his central organ is intact ; the condenser action between metallised diaphragm and skin conveys the vibrations direct to the hearing organs. Quality is extraordinarily good.

PHOTOTELEGRAPHY AND TELEVISION.

A PHONIC MOTOR AND SLAVE FORK AND AN ELECTRICALLY MAINTAINED TUNING FORK WITH A CALIBRATED SPEED ADJUSTMENT.—D. C. Gall. *See under* " Measurements and Standards."

MEASUREMENTS AND STANDARDS.

MAGNETOSTRICTION OSCILLATORS.—G. W. Pierce. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 42–88.)

This is the original paper (read before the Am. Acad. of Arts and Sciences) referred to in Abstracts, 1928, V. 5, p. 643. Among other interesting points may be mentioned the following : (1) The electrical feedback between grid coil and plate coil is the reverse of that usually employed in producing electrical oscillations : but with certain values of circuit constants the circuit will oscillate with the rod restrained from vibrating. When working on low frequencies (500–3,000 p.p.s.) it is preferable to work with the circuit in a non-oscillatory state : at higher frequencies (3,000–300,000 p.p.s.) it is more convenient and just as reliable to allow the system to be oscillatory even when the rod is restrained, and to employ the magnetostrictive rod merely to stabilise an already existing frequency ; (2) pure iron and irons with various carbon contents have too small a magnetostrictive effect : pure nickel is a good vibrator with some lack of stabilising power in that detuning slightly affects the frequency ; alloys of the two are good vibrators but have a large temperature coefficient of frequency ; alloys of chromium, nickel and iron are good, commercial Nichrome being one of the best practical materials. But, generally, in combinations of three metals a vanishing temperature coefficient is usually associated with non-magnetism or non-magnetostriction. Monel metal is a very powerful oscillator which has too small a residual magnetism to oscillate without an auxiliary polarising means (a small permanent magnet nearby is sufficient). Alloys of cobalt and iron are strong vibrators. By combining a tube of material with a negative temperature coefficient of frequency and a tight-fitting core of metal with a positive coefficient (*e.g.*, nickel tube with stoic metal core) a vibrator practically independent of temperature can be obtained. But even a simple Nichrome vibrator has a temperature coefficient of only − 0.00107/deg. C. ; (3) the author's curves, for alloys of various percentage compositions, of velocity of sound and of temperature coefficient of frequency of vibration suggest as a possible law that in a binary alloy the temperature coefficient of frequency is a maximum or minimum at the composition at which the velocity is a maximum or minimum *or the reverse ;* (4) all vibrators are improved by annealing ; (5) changes of plate voltage from 135 to 67 v. changes the frequency of the system (annealed Nichrome vibrator) by only 1 in 30,000.

An Elementary Theory of Dynamic Magnetostriction is given, while an appendix gives the more exact treatment including the Theory of the Propagation of Sound in a Viscous Magnetostrictive Medium. A short section deals with the magnetostrictive production of sound and ultra-sound, and another with the production of high-frequency stabilisation (best method probably the beaded rod, an example of which showed strong stabilisation of frequency 295,480 p.p.s.).

THE PIEZO-ELECTRIC CRYSTAL OSCILLATOR.—J. W. Wright. (*Proc. Inst. Rad. Eng.*, January 1929, V. 17, pp. 127–142.)

The original MSS. was submitted in April, 1928. The writer says that there are several very good articles on the piezo-electric crystal resonator, but that little information has been made available, for general use, concerning the operation and theory of the piezo-electric crystal oscillator. In this article he examines just what takes place when a zero-angle crystal is put in a typical oscillating crystal circuit. The crystal is first considered as a simple mechanical oscillator, and the required plate

circuit adjustment for sustained vibrations of the crystal is obtained by Miller's method, on the basis of an assumed electrically equivalent crystal circuit. The electrical equivalent of the crystal is then considered as the grid circuit of an oscillating valve circuit, and the equations for the frequency and condition for oscillation derived. The effects of the valve and of the circuit upon the frequency of a crystal-controlled oscillator are then shown: The former effect is evidenced by different frequencies given by the same crystal when controlling different types of valve: this is believed to be due to the difference in input capacity, and could be predicted from some of the equations arrived at earlier in the paper. It is mentioned finally that a crystal can be used to control the output frequency of an oscillator of the "relaxation" type, so that crystal-controlled oscillations which are subharmonics of the fundamental crystal frequency can be obtained.

VISUAL OBSERVATION OF PIEZO-ELECTRICAL OSCILLATIONS.—(*German Patent*, 467,629, Radiofrequenz, pub. 26th October, 1928.)

By suitable adjustment of the gap between upper electrode and crystal, optical phenomena render the oscillations visible. Observation is improved by enclosing in a more or less evacuated glass vessel.

PIEZO-ELECTRIC CRYSTAL PREPARATION.—(*German Patent*, 467,594, Telefunken, pub. 26th October, 1928.)

A crystal cut from a mother-crystal is sometimes imperfect because some silicon molecules remain sticking to the surfaces. It is here specified that the piezo-crystal should be washed with hydrofluoric acid.

PROTECTION AGAINST OVERLOADING A PIEZO-CRYSTAL.—(*German Patent*, 466,765, Telefunken, pub. 11th October, 1928.)

The use of a limiting tube (glow discharge ?) is specified, to protect the crystal from too violent oscillations.

AN AUXILIARY FREQUENCY CONTROL FOR R.F. OSCILLATORS.—G. F. Lampkin. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 115–117.)

The usual oscillator employs a variable condenser as a means of covering the frequency range. For greater precision, a small semi-circular plate condenser is often used in parallel as a vernier control. But even so, the value of cycle change per vernier-dial division will vary widely over the oscillator range, owing to the shape of the frequency-capacity curve. In the arrangement here suggested, the auxiliary (vernier) control operates on the element of the circuit which is *fixed : i.e.*, in the above case, the auxiliary control would be a variometer; while if the main control were a variometer and the condenser were a fixed one, the auxiliary control would be a small variable condenser. The frequency-change calibrations of the auxiliary control, for various settings of the main control, then become straight lines: the ratio of the slopes of these lines at 1,400 kc. and 625 kc. (in the example taken) is only about 2. Thus the value of cycles change per division of auxiliary control can be determined for each main control setting, and the resulting curve plotted and used. If the auxiliary control were made a small variometer, and the main control a straight-line-frequency condenser, the calibrations of both the main and auxiliary controls would be linear.

A DIRECT READING RADIO-FREQUENCY METER.—R. C. Hitchcock. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 24–34.)

A well-made tuned-circuit absorption type of wavemeter with a single variable condenser is reliable to about 2.5 kc. per sec. in the present (U.S.A.) broadcast band. The Bureau of Standards type, in which a small variable condenser shunted the large main fixed one, the coils being adjusted so that the waves to be measured came near the middle of the variable condenser, gave an increased accuracy. Recently an American firm has brought out an instrument which is guaranteed for six months to give a precision of 500 cycles p.s. when kept within ±5 deg. F. of the calibration temperature. The instrument here described is of another type—measuring the beat note produced with a calibrated crystal oscillator—and its scale divisions are 0.1 kc. apart, the accuracy (under reasonable conditions) being of this order. A new type of direct-reading audio-frequency meter having a useful scale of 2.0 to 4.5 kc. per sec., makes the device automatic. Like others of the beat-note type, it has the advantage that it can be operated at some distance from the radio source—several miles, if suitable audio amplification is provided. In cases where the circuit to be checked is liable to vary so much that it might give the correct beat note on the wrong side of the zero point, two standard crystal circuits are used, of slightly different frequency (either one above and one below the standard, or both on the same side), the combined behaviour indicating clearly on which side of zero beat the beat note lies. Warning devices can be operated by the note-frequency meter, through a grid-glow relay. As an indicating device a parallel resonant circuit loosely coupled to a milliammeter circuit can be used in place of the note-frequency meter. The special form of the latter instrument, referred to throughout the paper, is only described as of the tuned circuit type, with a useful scale spread over an arc of 90 deg.

L'ÉTALONNEMENT DES DIAPASONS SERVANT DE BASE AUX MESURES DES FRÉQUENCES RADIOTÉLÉGRAPHIQUES (The Calibration of Tuning Forks used for Radiotelegraphic Frequency Measurements).—B. Decaux. (*Comptes Rendus*, 21st January, 1929, V. 188, 316–317.)

Describes the frequency determination of an electrically driven fork by measuring a submultiple frequency (about 1/35); using Van der Pol's discovery (that relaxation oscillations can be

synchronised by a frequency higher than their natural frequency) to obtain this demultiplication. An A.C. of the fork's frequency was obtained by a microphone (not by using the driving current, as such use is liable to introduce complications) and after amplification was applied, in the form of a small P.D. at the terminals of a transformer, to the feed circuit of a neon tube. The capacity across the tube was varied till the frequency of the relaxation oscillations was near that of a sub-multiple of the fork frequency: synchronisation then took place. (This was confirmed by examination of the Lissajous figures produced in a cathode ray oscillograph, which also enabled the order of the submultiple to be determined if this could not be deduced by a knowledge of the approximate frequency of the fork.) The synchronised neon tube oscillations were registered and compared with the record of a wireless-controlled chronometer. The measurement was taken over a period of 5 minutes, and the accuracy was found to be 3 in 100,000.

VIBRATIONSRELAIS UND PHONISCHES RAD MIT UNTERBRECHER (Vibration Relay and Phonic Wheel with Interrupter.)—R. Skancke. (*Zeitschr. f. Instrkde*, No. 9, 1928, V. 48, pp. 432–438.)

In a paper on the Maxwell-Thomson method of absolute capacity measurement, the writer describes two pieces of apparatus which he has designed and used in place of the usually employed (and much more costly and complicated) rotating commutator and governor of Giebe.

AN ELECTRICALLY MAINTAINED TUNING FORK WITH A CALIBRATED SPEED ADJUSTMENT.—D. C. Gall. (*Journ. Scient. Instr.*, January, 1929, V. 6, pp. 18–19.)

A calibrated frequency scale reading from 48.5 to 51.5 cycles is provided upon the fork: an accuracy of setting of 0.1 per cent. can be relied on. The balance and damping is not affected by such adjustment, owing to the form of construction: an auxiliary fork, of much lighter construction, having the same length of limb but a much longer natural period, is coupled to the main fork only at the centre of the bobs; the two forks vibrate in unison, the frequency of the main fork being modified by the additional weight of the auxiliary bobs. The auxiliary fork is moved backwards and forwards by a screw adjustment, and this alters the centre of gravity of the weights and varies the frequency of the combination. The scale can be calibrated in temperature if it is desired to provide compensation for such change.

A PHONIC MOTOR AND SLAVE FORK.—D. C. Gall, (*Journ. Scient. Instr.*, January, 1929, V. 6, pp. 19–21.)

Description and curves of a Tinsley phonic motor: output available on shaft is about 10 W. with the best D.C. supply voltage 20 v., for fork speeds 20–50 cycles. It will run on voltages down to 5 v., but with decreased output. Large tungsten contacts are needed on the fork, easily renewed by the user. To prevent such a renewal from changing the frequency, a slave fork is used with a special adjustment to balance the limbs after re-setting the contacts: this slave fork is controlled by a standard fork with small contacts.

A BRIDGE CIRCUIT FOR MEASURING THE INDUCTANCE OF COILS WHILE PASSING DIRECT CURRENT.—V. D. Landon. (*Proc. Inst. Rad. Eng.*, December, 1928, V. 16, pp. 1771–1775.)

A bridge circuit is described in which the inductance of an iron core coil carrying D.C. is compared with resistances and a capacitance. In this way the trouble encountered in obtaining a satisfactory standard inductance is avoided. The voltage drop across the inductance is balanced against the drop across a resistance. The phase is corrected by the impedances in the other two legs. By reversing the positions of R_1 and the unknown, the bridge becomes the conventional one for measuring an impedance having resistance and capacity components. The paper concludes by comparing the bridge with those of Maxwell and Anderson. The writer considers the advantages of the Anderson bridge over the Maxwell to be very dubious, and prefers his own circuit which eliminates the divided D.C. path.

THERMO-COUPLE MILLIAMMETER AND AMMETER.—(*Journ. Scient. Instr.*, January, 1928, V. 6, p. 22.)

A Ferranti instrument primarily for radio frequencies, in moulded insulating case. Lowest range is to 25 mA. (also used for voltmeters), upper range to 5 A., all in the 2½-inch diameter size, with 2½-inch scale. The couples are insulated from the heater, so that there is no capacitance effect of the movement to earth and no reversal error on D.C. Consumption for the 25 mA. is about 20 mW. Successfully used on a 3-metre wavelength, but equally suited to commercial A.C. frequencies or D.C. Temperature compensation less than 0.1 per cent. per deg. C.

RECTIFIER VOLTMETERS, ETC.—(*Journ. Scient. Instr.*, January, 1929, V. 6, p. 23.)

Standard Ferranti 2½-inch radio-instrument movements combined with Westinghouse Copper-oxide rectifiers to produce A.C. instruments having high torque (equal to that of moving-coil instruments), efficient damping, very small current consumption which is constant for all ranges (unlike other A.C. voltmeters), and improved scale shape. Correct on all power-supply frequencies and wave-forms, not on peaked or other distorted wave-forms. Temperature error very small.

MEASUREMENT OF VERY SMALL D.C. CURRENTS.—J. Zenneck. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, p. 102.)

In his paper on "the Importance of Radiotelegraphy in Science," the author mentions that in the photometry of stars by means of the photoelectric cell, direct currents of the order of 10^{-14}A have to be dealt with. According to Rosenberg

it is possible, without appreciably affecting proportionality between light intensity and current, to amplify these currents about 100,000 times so as to measure them by a moving-coil galvanometer.

Elektronenzählrohr zur Messung schwächster Aktivitäten (Electron Counter for the Measurement of Very Small Energies).—H. Geiger and W. Müller. (*Naturwissen.*, No. 31, 1928, V. 16, pp. 617–618.)

A device of astonishing sensitivity which when unshielded in a room will register hundreds of deflections per minute from cosmic radiations, radiations from the walls, etc. Shielded by iron 25 cm. thick, it indicates about 50 impulses per minute. It consists of a thin wire stretched axially inside a metal tube. A voltage between tube and wire is prevented from causing a spark by a thin, very uniform insulating skin covering the wire. The arrival of an electron ray causes an ionisation current, which breaks off owing to the charging up of the skin. Each individual impulse is made evident on a string electrometer.

Experimental Methods for Determining the Distribution of Electric and Magnetic Fields.—B. Hague. (*Electrician*, 15th February, 1929, V. 102, pp. 185–187.)

"Problems demanding new methods of calculation; scope of mathematical methods; the graphical process; use of the magnetic potentiometer; the electrostatic probe." The magnetic potentiometer consists of a flexible non-magnetic core wound uniformly and closely with a coil of fine wire connected to a ballistic galvanometer; one end of the coil is kept fixed and the other moved suddenly from one point to another, the throw of the galvanometer being proportional to the difference of magnetic potential at the two points. The electrostatic probe depends on a telephone null method using a potentiometer. Du Bois' use of the iron filings method as a guide or check in accurate work (*e.g.*, on magnetic shielding), and the analogous fine powder method for electric fields, are discussed; the latter has been used successfully by Deutsch for investigating the field in three-core cables. The paper is to be continued.

Enregistrement photographique d'une Vitesse angulaire. Application aux Mesures balistiques (Photographic Recording of an Angular Velocity: Application to Ballistic Measurements).—A. Guillet. (*Comptes Rendus*, 14th January, 1929, V. 188, pp. 240–242.)

In a ballistic galvanometer, the source of light, instead of illuminating the slit continuously, illuminates it for very short periods at a frequency N. This is done by the use of a tuning fork, of frequency $N/2$, each of whose prongs carries a disc pierced at the centre with a very small hole, these holes being opposite when the fork is at rest. On development of the photographic film, a succession of points at intervals s measure the displacement of the spot during equal intervals $\frac{1}{N}$: the angular velocities of the moving systems are given by $\omega = \frac{sN}{2R}$ where R is the radius of the optical system. The film carrier can be moved by a micrometer adjustment, so that the same film can take a large number of measurements, either of ω (with the tuning fork in action) or of θ (tuning fork at rest).

Useful Data Charts (No. 21). Ratio of H.F. Resistance to D.C. Resistance of a Coil.—(*Wireless World*, 30th January, 1929, V. 24, pp. 120–122.)

One section of the text shows the effect of winding the same coil with different types of wire (solid, 9-strand Litz and 27-strand Litz). For coils for short waves, where Litz stranding is worse than useless, S. Ward's proposal is mentioned—to split up the solid wire into a series of adjoining strands connected in parallel and wound on like tape; thus giving a truly single-layer winding with uniform spacing.

Methods for the Derivation and Expansion of Formulas for the Mutual Inductance of Coaxial Circles and for the Inductance of Single-layer Solenoids.—F. W. Grover. (*Bur. of Stds. Journ. of Res.*, October, 1928, V. 1, pp. 487–511.)

A paper giving a classification of existing inductance formulæ for the general cases mentioned. A number of new ones are developed which can be used to advantage in certain cases. It is shown by examples that in any given case the inductance can be calculated by more than one formula and to a precision far beyond practical requirements. A long bibliography is added.

Alternating Current Bridge Methods: Their Application to Electrical Engineering Problems, with Special Reference to the Testing of Synchronous Condensers. Part I.—R. G. Churcher. (*Electrician*, 9th November, 1928, V. 101, pp. 518–520.)

Misura delle Correnti ad alta Frequenza con Metodo fotometrico (H.F. Current Measurement by a Photometric Method).—G. Pession and T. Gorio. (*L'Elettrotec.*, 25th November, 1928, V. 15, pp. 870–872.)

A tungsten filament is heated to incandescence by the current to be measured, and its radiation measured by a photoelectric cell and suitable adjuncts.

Demonstration statischer Hochspannungsvoltmeter (Demonstration of a Static H.T. Voltmeter).—H. Starke. (*Vortragshandbuch* 90 Versamm. d. Ges. Deut. Nat. forsch., Hamburg, September, 1928.)

The electric field between two high-tension electrodes exerts a rotating effect on a small vane attached to a stretched thread; in its zero position the vane rests in a small slit in the one electrode, and is so small that the field distortion arising from its rotation extends only to its immediate neighbourhood. As a result the calibration is the same

for all the electrode gaps used: *i.e.*, the scale remains the same for a number of ranges, and once calibrated on a low range (*e.g.*, 3–10 kV.) is correct for all the ranges up to the limit of insulation. Deflection is aperiodic, in 1.5 second.

An Absolute Current-Balance having a Simple Approximate Theory.—L. F. Richardson and V. Stanyon. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, pp. 36–42.)

The simplification of the theory is attained by making the length of the coils five or six times their diameter, instead of using narrow rings (Rayleigh and Mrs. Sidgwick) or coils having a length about 0.65 of their diameter (N. P. L., 1907).

A New Microammeter. (*Journ. Sci. Inst.*, December, 1928, V. 5, p. 387.)

Brief description and illustration of a new Ferranti instrument serving as a portable quick-acting galvanometer for null tests, and as a calibrated microammeter (250–0–250, 10 microamperes per division: resistance 60–70 ohms).

A New Alternating Current Potentiometer of Larsen Type.—A. Campbell. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part I, pp. 94–99.)

The main object of the new system is to make the instrument read the in-phase and quadrature components of the unknown voltage *directly*. As emerges from the subsequent discussion, the new instrument should be specially useful for acoustical work in which the distribution, reflection, etc., of sound is measured by microphones, the source of sound being a loud speaker actuated by A.C. of pure wave-form. The instrument requires no phase-splitting device and uses a very small amount of power. It is particularly useful for the accurate measurement of very small voltages and current (*e.g.*, a few microamperes), for in both cases the scale does not follow the square law but gives direct proportionality, which is an enormous gain at the low readings.

A Device for Accurate Timing.—H. L. Johnston. (*Journ. Opt. Soc. Am.*, November, 1928, V. 17, pp. 381–385.)

In the particular case, astronomical time signals at second intervals were used to operate a circuit once per minute. The device includes a pawl-and-sprocket drive as used in a pedometer. The whole was calibrated on the Cornish-Eastman method (*Journ. Am. Chem. Soc.*, p. 627, 1928) by comparing a four-minute interval controlled by the device with the number of oscillations of a high frequency oscillating circuit of constant frequency: it was found to possess "an accuracy of better than 3×10^{-3} sec. for any integral number of minutes."

Die Bestimmung der Durchschlagfestigkeit von festen Stoffen in homogenen Felde (Determination of Dielectric Strength of Solid Materials in Homogeneous Fields).—E. Marx. (*E.T.Z.*, 10th January, 1929, pp. 41–44.)

Methods and results of the latest measurements, taken with specially designed electrodes and test-samples, under a suitable liquid.

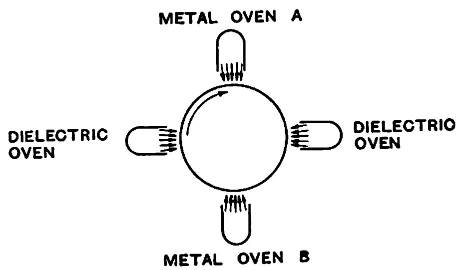
Die Bestimmung der Lichtgeschwindigkeit unter Verwendung des elektrooptischen Kerr-Effektes (Measuring the Velocity of Light by the Electro-optical Kerr Effect).—A. Karolus and O. Mittelstaedt. (*Physik. Zeitschr.*, 1st October, 1928, pp. 698–702.)

A Bridge for Measuring Audio-frequency Transformers, Etc.—G. Koehler. (*See under* "Acoustics and Audio-frequencies.")

SUBSIDIARY APPARATUS AND MATERIALS.

Der Weg zum Farad (The Achievement of Farad Condensers).—v. Hartel. (*Rad. f. Alle*, December, 1928, pp. 552–556.)

The writer begins by pointing out the desirability of large capacities such as one farad, if they could be obtained within reasonable dimensions, at reasonable cost, to stand useful voltages: *e.g.*, for smoothing rectified A.C. He then describes recent research on the dielectric strength of very thin dielectrics, which has shown that whereas for normal thicknesses the breakdown voltage may be, say, 100,000 v/cm., for very thin layers where ionisation by collision is enormously reduced (between .001 and .0001 mm.) the value may be 300,000,000 v/cm. He goes on to describe the method recently patented by Polanyi to make use



of this result: a method which is at present being developed and backed by a large capital, for the manufacture not only of large-capacity condensers (a farad in a volume of about 120 c. inches, with a breakdown voltage of 1,000 v.) but also of thin insulating layers for laboratory and other purposes, to withstand 50 kV. per 0.1 mm. The schematic idea of the process of manufacture is shown in the diagram.

A drum rotating at 8,000 r.p.m. is contained in a vacuum of 1/10,000 mm. mercury, and can be cooled by a liquid led in through its axis. The four electrically heated ovens contain alternately metal and insulating material, which volatilise and deposit themselves on the rotating drum. At either end, a pair of screens shut off one metal and one insulator oven, so that here the alternate metal layers overlap and form one pole of the final condenser. By adjusting the oven-temperatures and the speed of rotation, the thickness of dielectric and metal films can be adjusted, down to a molecular thickness. A one-farad condenser takes a few minutes only to manufacture.

A UNIQUE METHOD OF CONTROL BY MEANS OF SOUND WAVES.—A. B. Du Mont. (*QST*, January, 1929, V. 13, pp. 41–42.)

A change-over switch (*e.g.*, for switching on and off a broadcast receiver, or—in testing—for switching from the standard circuit to the one under test) is operated at a distance by a low-frequency sound impulse caused by clapping the hands together, cup-shaped. The sound-operated circuit-breaker consists of a light tab of copper resting on two copper wires. This operates a simple self-setting relay whose construction is described.

DIE SELBSTREGELNDEN HARASTATE-WIDERSTÄNDE (Self-regulating Harastate Filament Resistances). (*Rad. f. Alle*, December, 1928, pp. 560–561.)

According to the writer, the iron-wire automatic regulating resistance has had a complete revival in America. A new German make, the " Harastate," is referred to and strongly recommended.

SUPPRESSION OF DISTURBING PULSATIONS IN H.F. GENERATORS. (*German Patent* No. 466,630, Lorenz, pub. 9th October, 1928.)

Such machines have a very small air-gap compared with the rotor diameter, so that the necessarily imperfect centering of the rotor produces current fluctuations. In the invention, these are counteracted by opposing impulses from a rotary transformer mounted on the axle: its rotating field winding is connected across the H.F. terminals, while its stator winding is in series with the H.F. output circuit.

GOVERNOR FOR H.F. GENERATORS. (*German Patent* No. 465,984, Lorenz, pub. 28th September, 1928.)

A tuned circuit for the correct frequency is coupled to the generator circuit: in resonance, the voltages at the inductance and the capacity are equal; they are conveyed to the windings of a differential H.F. relay, the action of which regulates the speed of the generator.

CENTRIFUGAL GOVERNOR. (*German Patent* No. 465,964, Telefunken, pub. 28th October, 1928.)

In a centrifugal force, gravity, and spring governor much resembling those referred to in recent Abstracts, an additional adjusting force is supplied by making the weight of soft iron and providing a magnetic field to act on it as it passes.

THE DIVERTER POLE GENERATOR FOR BATTERY-CHARGING.—E. D. Smith. (*Journ. Am.I.E.E.*, January, 1929, V. 48, pp. 11–15.)

A new type of generator developed to overcome certain limitations inherent in the shunt and compound generator when used for charging batteries by the constant voltage, modified constant voltage, or floating methods. A small diverter pole spaced midway between each pair of main poles has a magnetic bridge connecting it to one of these main poles. A restricted section in this bridge (produced by a hole through it) limits the leakage from the main pole and also acts as a magnetic choke which regulates the magnetism passing to the armature from the diverter pole, which has a winding in series with the load circuit. The resultant effect, which is fully described and illustrated by flux distribution and voltage regulation curves, is to give a machine with a number of advantages for the purposes mentioned.

TUNGSTEN FILAMENT VACUUM FUSES. (*Gen. Elec. Review*, January, 1929, V. 32, pp. 37–38.)

One D.C. fuse mentioned (rated at 10 A. at 15,000 v.) will rupture a current of 45 A. at that voltage. Another, for the protection of instrument transformers (rated at $\frac{1}{2}$ A. at 13,200 v.) will rupture a current of 110 A. When the tungsten filament burns out, one remaining end is hot enough to emit electrons which temporarily carry the current. In the case of the D.C. fuse, the emission quickly and smoothly falls to zero as the point cools; in the case of the A.C. fuse, it ceases as the current wave passes through the zero point.

VAKUUM ALS ISOLATOR (A Vacuum as Insulator).—W. Malischew, N. Semenov and N. Tomaschewsky. (*Journ. Applied Phys., Moscow*, No. 3/4, 1928, V. 5, pp. 93–118.)

A new theory of the breakdown of a high vacuum is evolved. By simple outgassing of the electrodes, the writers have obtained an insulation standing up to 400 kV. with a leak of only $1–2 \times 10^{-6}$ A/cm.^{2}

THEORIE VAN DEN OSCILLOGRAAF: BEWEGUNG VAN EEN ELECTRON IN EEN VELD VAN HOOGE FREQUENTIE. PRACTISCHE METHODE VOOR HET BEPALEN VAN PHASEVERSCHILLEN (Theory of the Oscillograph: Motion of an Electron in a H.F. Field; Practical Method for Determining Phase Displacement).—A. v. Itterbeek. (*Tijdschr. Wiss. en Natuurk*, No. 2/3, 1928, V. 4, pp. 47–59.)

In connection with his cathode ray oscillograph (500–1,000 v.) the writer investigated the mathematical theory of the instrument, depending on the behaviour of an electron in a H.F. field. For frequencies greater than 2×10^7, the time taken by an electron to pass from between the deflecting plates must be considered. A consideration of the special case where the deflecting systems are not at right angles to one another leads to a practical method of measuring phase differences.

AN OPTICAL OSCILLOGRAPH.—(*Phys. Review*, No. 2, 1928, V. 32, p. 319.)

A light ray passes through a Nichols prism, which polarises it in one plane; then through a quartz plate, which rotates the plane according to the equation $\delta = A + B/\lambda^2$; then through a carbon disulphide cell surrounded by a coil through which the current under examination passes. This cell increases or decreases the rotation, according to the current fluctuations through the coil. The ray then passes through a second Nichols prism, which cuts off all wavelengths rotated through $n\pi$ (n being a whole number). The ray is now observed through a spectroscope; a spectrum consisting of light and dark bands is obtained, in which the

position of the dark bands depends on the strength of the current through the coil. The use of a rotating mirror allows the current variations to be registered on a photographic film.

ÜBER EINEN NEUEN KOHLEWIDERSTAND (A New Carbon Resistance).—Hartmann and H. Dossmann. (Abstract in *Vortragshandbuch*, 90 Versamm. d. Ges. Deut. Nat. forsch., Hamburg, September, 1928).

A resistance applicable not only to valve circuits but also to D.C. and A.C. measuring purposes, including high voltage work. It is made by depositing a very thin layer of clean crystalline carbon (from the anthracite series) on an insulating surface, in a stream of carburetted hydrogen at 900–1,000 deg. It can be made for resistance between 10 and 10^7 ohms ; it is very constant and will stand very heavy overloads beyond the normal load of half a watt per sq. cm. No further details are here given. *Cf.* Seth, Anand and Chand, under "Miscellaneous."

A HIGH SPEED GRAPHIC VOLTMETER FOR RECORDING MAGNITUDE AND DURATION OF SYSTEM DISTURBANCES.—A. F. Hamdi and H. D. Braley. (*Journ. Am. I.E.E.*, July, 1928, V. 47, pp. 512–515.)

Normally the record-paper moves at the rate of only 3 cm. per hour, but the arrival of a certain over-voltage speeds it up to 10 cm. per sec., with a lag of 0.28 sec.

STATIONS, DESIGN AND OPERATION.

WHO'S WHO IN THE ETHER : A GUIDE TO DISTANT RECEPTION, COMPRISING A LIST OF EUROPEAN BROADCASTING STATIONS WITH THEIR WAVELENGTHS, CALL-SIGNS, AND IDENTIFICATION SIGNALS.—(*Wireless World*, 6th February, 1929, V. 24, pp. 149–151.)

GLEICHWELLEN-RUNDFUNK (Common Wavelength Broadcasting).—H. Göttinger. (*Rad. f. Alle*, November, 1928, pp. 501–503.)

In spite of rumours, inside and outside Germany, no common wavelength broadcasting has made its appearance : reports show that it was unsuccessfully tried in England. The writer, however, thinks it may yet be developed, and outlines the principles, the advantages and the difficulties of such a system. The Berlin G.P.O., working with Telefunken and Lorenz, appears to have solved the problem successfully in trials. Telefunken use a fundamental frequency of 30,000 p.p.s. transmitted by overhead lines to the various stations and there stepped up by valves working on the bend of the characteristic : four frequency-doubling stages are used, resulting in a frequency of 480 kilohertz. Lorenz starts with a lower frequency, 2,500, which can be transmitted by cable : at the stations it is stepped up by the Lorenz H.F. generator, to give a final wavelength round 530 m. The final trials were with three stations round Berlin. Stettin is now to be included, so that a four station group will soon be working. The trouble of "interference zones" (due to the production of stationary waves) is described : it is thought that an increasing number of stations will diminish such zones and that they can be located in a little-populated district.

HIGH POWER BROADCASTING TRANSMITTERS.—(*Gen. Elec. Review*, January, 1929, V. 32, p. 41.)

"Decided improvements in the design . . . were effected by the utilisation of recently-developed water-cooled pliotrons having a nominal rating of 100 kW. With two of these tubes in the output stage the transmitter is capable of delivering 100 kW. to the antenna and this power is modulated 100 per cent." (*Cf.* Nelson, under "Transmission.") This transmitter is regularly operated on WGY programmes at an output of 50 kW., and a high degree of frequency stability is obtained by means of quartz crystals.

DIE NEUEN RUFZEICHEN (The New Call Letters).—(*Rad. f. Alle*, December, 1928, p. 568.)

A list of the new national call prefixes which came into force on 1st January, 1929.

SYDNEY TALKS TO NEW YORK : AUSTRALIA'S LATEST SHORT-WAVE FEAT.—(*Wireless World*, 30th January, 1929, V. 24, pp. 119–120.)

An account of the November, 1928, demonstration to the Press of telephonic communication from Sydney to Bandoeng (Java : 2,000 miles) and Schenectady (New York : 10,000 miles). Sydney worked on 28.5 m. and used a 20 kW. transmitter, some details of which are given. The demonstration began at 10 p.m.

TABELLE DER WICHTIGSTEN KURZWELLENSENDER (Table of the Most Important Short Wave Stations).—(*Rad. f. Alle*, November, 1928, p. 511.)

Wavelengths vary from 104 m. (Mailand) down to 13.6 m. (Geizers Hill, 9 CH).

EIN BLICK IN DIE FUNKKABINE DES "GRAF ZEPPELIN" (A Glimpse into the Wireless Cabin of the "Graf Zeppelin.")—(*Rad. f. Alle*, December, 1928, pp. 557–558. See also *Telefunk. Zeit.*, October, 1928, pp. 49–50.)

GENERAL PHYSICAL ARTICLES.

THE ELECTROMAGNETIC EQUATIONS IN THE QUANTUM THEORY.—C. G. Darwin. (*Nature*, 9th February, 1929, V. 123, p. 203.)

By the methods of Schrödinger it is possible to express the radiation of atoms in the form of electromagnetic waves, but the formulation is quite incomplete, because it fails to give the reaction of the radiation on the emitting system. The theory of Dirac is free from this cardinal fault, but fails to show the relation of radiation to static electric force ; it is, in fact, a valid theory of light, but scarcely an electromagnetic theory. The present letter shows the outline of how we may hope that the old waves, with their Maxwellian equations, can be fitted almost without change

into the new scheme, when certain difficulties (involving the idea of superposed *times*) have been solved. The direct interactions of particles according to relativity principles will probably do away with the actual need for the idea of radiation: but the latter will always remain a convenient eliminant, expressive of the effect of a number of particles on a distant one.

THE UNDERSTANDING OF RELATIVITY.—(*Nature*, 2nd February, 1929, V. 123, pp. 160–161.)

Continuation of the correspondence referred to in recent Abstracts. Lodge—as an example of "uninstructed common sense" being occasionally a bad guide—quotes the velocity of light in water flowing in the same direction: as predicted by Fresnel and found by Fizeau, it is definitely not $c/\mu + v$ (velocity in stagnant water plus velocity of water) but this sum less v/μ^2. He mentions that the Larmor-Lorentz transformation, from which this and other "queer rules of composition" follow, was invented some years before Einstein boldly applied it to actuality.

REFRACTION OF BEAMS OF MOLECULES.—I. I. Rabi. (*Nature*, 2nd February, 1929, V. 123, pp. 163–164.)

As a more precise optical analogy than the Stern-Gerlach experiment, the writer investigates (theoretically) the refraction of a beam of molecules travelling from a region of no magnetic field to another in which there is a homogeneous magnetic field. He obtains $\delta = \frac{\mu H}{2E} . \tan \theta$ (where μ is the Bohr magnetron, E the kinetic energy of the molecules, θ the angle of incidence), provided that the ratio $\mu H/E$ is small. A complete discussion, including an experimental investigation, is to appear in *Zeitschr. f. Phys.*

POSITIVE ION CURRENTS IN THE POSITIVE COLUMN OF THE GLOW-DISCHARGE IN THE NOBLE GASES.—W. Uyterhoeven. (*Proc. Nat. Acad. Sci.*, January, 1929, V. 15, pp. 32–37.)

The author's results with Ne, Ar and He present two discrepancies with Langmuir's results with mercury vapour; namely, an increase of i with decreasing collector-potential, and the difference between i_m (the measured value) and i_c (the value calculated by Langmuir's theory): i_c being only about half i_m. Various explanations are discussed: not one of them can be singled out as free from objections: one of the most probable would seem to be secondary emission from the metal plate due to the impact of metastable atoms; but even here the efficiency of the process must be assumed rather high, *e.g.*, 50 per cent. A more complete record is promised to follow.

THE ABSORPTION OF PENETRATING RADIATION.—L. H. Gray. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 647–668.)

Adopting the hypothesis that penetrating radiation is a type of gamma radiation, its absorption in the atmosphere is investigated from the theoretical standpoint.

SKIN EFFECT IN RECTANGULAR CONDUCTORS AT HIGH FREQUENCIES.—J. D. Cockcroft. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 533–542.)

A treatment by electrostatic analysis. At high frequencies the surface of the conductor becomes a stream-line in the magnetic field, and the problem of distribution of current becomes analogous to an electrostatic problem: surface current density corresponds to E.S. surface density, and depth of penetration is the same as for infinite strips.

LA DIFFRACTION DES ÉLECTRONS PAR DES POUDRES CRISTALLINES (Electron Diffraction by Crystalline Powders).—M. Ponte. (*Comptes Rendus*, 14th January, 1929, V. 188, pp. 245–246.)

The writer has obtained such diffraction by the use of an arrangement similar to that employed in the study of powders by X-rays. He points out that his results show the possibility of studying the crystal lattice of a substance by the aid of electrons without the necessity for a delicate technique such as is involved in the preparation of the thin films used by G. P. Thomson and Rupp. His method gives the analysis in a short time (1 to 1½ hrs.) with the expenditure of little power (35 W for $V = 17$ kV.). Moreover, it lends itself to the study of positive ions and the determination whether these, like the electrons, are accompanied by an associated wave.

ACTIONS MAGNÉTIQUES LONGITUDINALES SUR DES FAISCEAUX D'ÉLECTRONS LENTS (Concentrations et Dilatations périodiques)—(Longitudinal Magnetic Effects on Rays of Slow Electrons—periodic Concentrations and Dilatations).—J. Thibaud. (*Comptes Rendus*, 2nd January, 1928, V. 188, pp. 54–56.)

The authors have experimented on rays of slow electrons, obtained in a bronze cylinder 30 cm. long and 12 cm. in diameter, very thoroughly exhausted. Such a ray can be obtained with voltage as low as 16 v., and possesses properties (comparable with those of soft X-rays) which disappear when 500 v. is reached: *e.g.*, the whole of its path is visible owing to fluorescence of the gas molecules. If a magnetising coil inside the cylinder coaxial with the ray is energised, the direction of the ray is hardly affected, though its glow is brightened. But if the magnetising current is varied continuously by a rheostat, the pencil of rays periodically dilates and contracts, varying from a wide-ended cone (diam. 100 mm. at 30 cm. from the source) to a brilliant and fine pencil (0.2 mm. diameter). The values of magnetic field producing the concentration effect are obtained by making $n = 1, 2, 3 \ldots$ in the equation $H_c = K(n - \frac{1}{2})\beta$, where K is a constant for the particular apparatus and β is the velocity of the electrons; while $H_d = Kn\beta$. The tests included the use of fields from 2–450 gauss and of electron energies of 16-1,100 v. The authors have established a theory of these phenomena, not given here. The subject is dealt with further in the next issue (7th January, pp. 158–160).

MATHEMATICAL STUDY OF A RECTIFIED ALTERNATING CURRENT.—G. Poux. (*L'Industrie Élec.*, 25th August, 1928, V. 37, pp. 365–372.)

BEMERKUNG ZUM HARMONISCHEN ANALYSE (A Note on Harmonic Analysis). — G. Duffing. (*E.T.Z.*, 25th October, 1928, p. 1592.)

Describes a mathematical procedure, first proposed by the writer in 1916, which should be useful to experts, as it allows them to entrust the work to assistants who need only be accurate computers.

HEAVISIDE'S FORMULÆ FOR ALTERNATING CURRENTS IN CYLINDRICAL WIRES.—T. J. I'a. Bromwich. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 842–854.)

The writer gives for the first time proofs of certain of Heaviside's formulæ and directs attention to the advantages obtained by using these Bessel-function formulæ instead of "the much less convenient solutions" obtained later by Kelvin in terms of *ber* and *bei* functions.

THE PRACTICAL APPLICATION OF THE FOURIER INTEGRAL.—G. A. Campbell. (*Bell Tech. Journ.*, October, 1928, V. 7, pp. 639–707.)

The growing practical importance of transients and other non-periodic phenomena makes it desirable to simplify the application of the Fourier integral in particular problems of this kind, and to extend the range of problems which can be solved in closed form by this method. 45 pages of tables facilitate such employment by the physicist.

ÜBER DIE URSACHE, WARUM EIN ELEKTRISCHES ELEMENTARQUANTUM NICHT IN TEILE VON NOCH KLEINEREN LADUNGEN ZERFALLEN KANN (The Reason why an elementary Quantum of Electricity cannot disintegrate into still smaller charges).—W. Anderson. (*Ann. der Physik*, No. 20, V. 87, pp. 536–542.)

THE STRUCTURE OF MOLECULES. — F. Hand. (*Nature*, 29th December, 1928, V. 122, p. 1010.)

Summary of the fourth paper on the significance of molecular spectra (*Zeitschr. f. Phys.*, 12th November, 1928).

SCHRÖDINGER DYNAMICS.—A. Bramley. (*Journ. Franklin Inst.*, November, 1928, V. 206, pp. 605–621.)

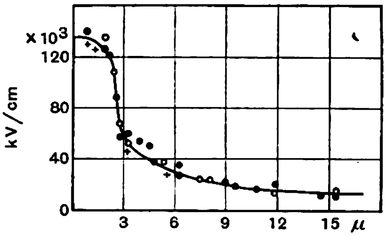
AN UPPER LIMIT FOR ENERGY-DENSITY: THE STRUCTURE OF TIME.—G. I. Pokrowski. (*Zeitschr. f. Phys.*, 2nd November, 1928, V. 51, pp. 730–739.)

Two papers, in the first of which various ways of treating the subject lead to 3×10^{12} deg. as the maximum possible temperature, 10^{13} g./cm.^{3} as the highest probable energy-density, and n as the maximum frequency for radiation, where $\log n = 24$ approx.; in the second paper a time of the order of 4.5×10^{-24} is proposed as the ultimate element.

MISCELLANEOUS.

DIE ELEKTRISCHE FESTIGKEIT DÜNNER SCHICHTEN (The Electrical Strength of Thin Films).—A. Joffe. (*Summary in E.T.Z.*, 31st January, 1929, pp. 169–170.)

The writer, investigating the effect of decreasing the possible ionisation by collision by decreasing the path from one electrode to the other, has worked on glass films down to 0.014μ in thickness and on mica down to 0.05μ, while with oil, benzol, pizein and colophonium he has tested from thicknesses of 15μ down to about 1μ. With all these materials, as the thickness is reduced below 5μ the dielectric strength rapidly mounts (*see* curve).



Tests on the still thinner glass and mica, however, showed that though the breakdown voltage rose to about 150,000 kV/cm. for a thickness of 0.2μ, a further diminution of thickness produced no further rise. This steady value is, he considers, the "true" dielectric strength of the material. *Cf.*, v. Hartel, under "Subsidiary Apparatus."

VELOCITY OF PARTICLES SPUTTERED BY DISRUPTIVE DISCHARGE.—H. Nagaoka and T. Futagami. (*Proc. Imp. Acad. Tokyo*, No. 5, 1928, V. 4, pp. 201–204.)

Rotating film records indicate speeds varying from 10–130 metres per sec.

INSULATION: THE OPPORTUNITY FOR RESEARCH.—J. B. Whitehead. (*Journ. Am. I.E.E.*, January, 1929, V. 48, pp. 27–31.)

A short survey of our present knowledge, pointing out the need for research on the size, motion and other characteristics of the mobile ions, their accumulation as space charges, and their relation to the chemical constitution, origin and subsequent states of the dielectric material. Results of physicists such as Debye and his followers (associating S.I.C. with inherent molecular dissymmetry) and Euguchi (with his "electrets" with permanent electrification similar to permanent magnetism) are important and stimulating but throw little light, for example, on the nature of dielectric absorption and loss.

DIE ELEKTRISCHE LEITFÄHIGKEIT DES SILIZIUSM (The Electrical Conductivity of Silicon).—H. J. Seemann. (*Summary in E.T.Z.*, 24th January, 1929, p. 134.)

Silicon, like Carbon, Titanium, etc., has a negative temperature-characteristic. Ryschkewitsch has shown that single graphite crystals have a positive

coefficient (and a conductivity exceeding that of mercury). The writer has now found that single silicon crystals, also, have a positive coefficient. It looks, therefore, as if in all these cases the negative coefficient is a result of polycrystalline structure and consequent oxidised surface-layers.

SUR LA RECTIFICATION PAR LES MAUVAIS CONTACTS PUREMENT MÉTALLIQUES (Rectification by Purely Metallic Imperfect Contacts).—H. Pélabon. (*Comptes Rendus*, 28th January, 1929, V. 188, pp. 382–384.)

An apparently perfectly symmetrical arrangement of one steel cylinder standing on another, identical, cylinder, with a few grains of lycopodium or cork powder separating them, presents curious properties. When brought to a condition of fatigued coherence (by the regular application, at 30 sec. intervals, of electromagnetic impulses) it shows equal conductivity in the two directions, and yet when an alternating current is applied, a rectifying action appears, always in the direction of the upper cylinder. The only lack of symmetry is that the upper cylinder is free to move while the lower, standing on a hard surface, is fixed. If now the lower cylinder is placed on a " giving " surface such as a piece of woollen material, the rectifying action vanishes. The force of " electrostatic pressure," invoked by Blanc for the explanation of coherer-action, is evidently involved. The paper concludes by a consideration of the rectifying action of two steel spheres, suspended by wires of equal length and touching each other.

" THE TRANSMITTING STATION ACTUALLY SENDS OUT WAVES OF ONE DEFINITE FREQUENCY, BUT OF VARYING AMPLITUDE."—A. B. Howe. (*E.W. & W.E.*, February, 1929, V. 6, pp. 95–96.)

A continuation of the argument referred to in February Abstracts. One particular point here dealt with is the reason why, if we listen to the second harmonic of a modulated radio-frequency wave, we do not observe all the tones of the modulation to have been raised in pitch by one octave. The mathematical treatment given shows that we shall hear the original modulation and not the octave, but that a certain amount of harmonics of the original modulation frequencies will always be present, introducing more or less distortion—as is found in practice.

A FILTER FOR STREET CAR NOISES.—(*QST*, January, 1929, V. 13, p. 45.)

Summary of a report by an official of the San Diego Electric Railway Company. A suitable filter, between trolley-wheel and motors, was found very effective so far as commutator-generated interference was concerned, but not very useful as regards trolley-wheel spark interference, which could only be minimised by care in the maintenance of the contact-parts.

THE PHYSICAL SOCIETY'S EXHIBITION: MATTERS OF WIRELESS AND LABORATORY INTEREST.—(*E.W. & W.E.*, February, 1929, V. 6, pp. 81–85.)

HUMOURS OF THE MARKET SURVEY: OURSELVES AS OTHERS SEE US: FOREIGN IMPRESSIONS OF THE BRITISH WIRELESS POSITION.—(*Electrician*, 9th November, 1928, V. 101, p. 525.)

WEITERE MITTEILUNGEN ZUM KRISTALLDETEKTORPROBLEM (Further Information on the Subject of the Crystal Detector).—P. Beck. (*Physik. Zeitschr.*, No. 13, 1928, V. 29, pp. 436–437.)

As an extension of Reissaus' contribution to the problem, the author describes experiments, on various galena contacts, in which the electrical measurements were taken simultaneously with microscopical observations of the active spot.

SUR L'ÉTUDE DES CONTACTS IMPARFAITS EN COURANTS CONTINUS (The Study of Imperfect Contacts with Continuous Currents).—R. Audubert and M. Quintin. (*Comptes Rendus*, 26th November, 1928, V. 187, pp. 972–974.)

Most imperfect contacts give rectification through a combination of various phenomena—electronic, thermoelectric and electrolytic. This paper deals with the Silicon-Carbon contact: here the effects are instantaneous, reversible and stable: the thermoelectric effect is opposed to the rectifying effect: the hypothesis of solid electrolysis cannot be invoked. The action depends on a skin of oxide: when this skin is gradually thickened the dissymmetry of the two parabolic branches of the current-voltage curve increases, passes through an optimum, and then decreases. But the critical voltage, beyond which the unilateral conductivity disappears, increases regularly with the thickness of the skin. Increase of pressure diminishes the dissymmetry, the characteristic tending towards a straight line. Increase of temperature gives a similar effect. Curves are given showing this, and the conclusion is that this combination is particularly well suited to the study of the mechanism of rectification.

SUR LE MÉCANISME DE LA CONDUCTIBILITÉ DISSYMÉTRIQUE DES CONTACTS IMPARFAITS (The Mechanism of Unsymmetrical Conductivity in Imperfect Contacts).—R. Audubert and M. Quintin. (*Comptes Rendus*, 2nd January, 1929, V. 188, pp. 52–54.)

Referring to the above paper, the writers say: " If one considers the conductivity as due to a pure electronic displacement, such a régime should be represented by Maxwell's law, *i.e.*, by the first part of the saturation curve of thermionic emission before the intervention of the space charge. Experiment does not confirm this idea, since the intensity (of current) varies as the square of the P.D." They go on to show that experiment and theory fit in well together for the silicon-carbon contact if it is supposed that ionisation intervenes—as is probable in view of the presence of absorbed or occluded gases in the carbon; and conclude that for this contact and also, probably, for silver and lead sulphide contacts, the mechanism is electronic emission accompanied by ionisation.

Über Kontaktwiderstände (Contact Resistances).—R. Holm. (*Vortragshandbuch*, 90 Versammlung der Gesell. Deutscher. Nat. Forsch., Hamburg, September, 1928; also shorter abstract, *E.T.Z.*, 13th December, 1928, p. 1814.)

Conduction between technically clean pieces of metal is principally metallic: the contact has a selective resistance. The proof of this lies particularly in the voltage-resistance characteristics. These can be plotted with electric and thermal specific conductivities as parameters. Experimental results conform very well with the theory, which shows a uniform proportion of temperature at the contact to contact voltage. Recrystallisation temperature shows a first resistance-drop, melting point a second. A cohering contact surface is only obtained at specific pressures. So-called "smooth" surfaces for the most part touch each other only in individual spots, where they display contact resistance which, like the friction, depends only on the total pressure and not on the magnitude of the apparent surfaces of contact.

Effet du Champ magnétique sur la Résistance Électrique d'un Contact (Effect of a Magnetic Field on the Electrical Resistance of a Contact).—J. Cayrel. (*Comptes Rendus*, 26th December, 1928, V. 187, pp. 1287–1288.)

For a field of about 20,000 gauss, results were negative for all the contacts tried except the contact Bismuth-Bismuth, where it was positive, though much less marked than for bismuth wire; and it increased as the contact resistance decreased, *i.e.*, as the contact became more intimate and therefore more like a homogeneous metal.

Single Side-band Carrier for Inter-station Communication.—R. Wilkins and F. I. Lawson. (*Elec. World*, 3rd November, 1928, V. 92, pp. 877–881.)

The suppressed-carrier system adopted by the Pacific Gas & Electric Company for communication over its 110–220 kV. network.

Resonant Control for Multiple Street Lamps.—W. W. Edson. (*Elec. World*, 10th November, 1928, V. 92, pp. 929–932.)

Frequencies of 720 and 480 p.p.s. are used, travelling along the 4,000 v. circuit, through the distribution transformers and to the various street lamps, each of which has two tuned relays in the base of the post.

The Geometry of Resonance Diagrams.—J. K. Catterson-Smith. (*Engineering*, 5th October, 1928, V. 126, pp. 415–416.)

A description, with examples, of the use of a graphical method of solving resonance problems, the determination of decrement, H.F. resistance, etc.

Mathematical Symbols. (*E.T.Z.*, 1st November, 1928, p. 1625–1627.)

Tables recently issued by the German Committee for Units and Dimensions.

Lichtenberg Figures.—C. E. Magnusson. (*Journ. Am.I.E.E.*, November, 1928, V. 47, pp. 828–835.)

Testing Installation for 500,000 Volts at the Electrotechnical Laboratory, Italy. (*Génie Civil*, 20th October, 1928, V. 93, p. 389.)

The plant was supplied by a Dresden firm and operates on the plan of charging blocks of condensers in parallel and connecting in series.

Beitrag zur Allgemeinen Theorie der Elektrostatischen und Elektromagnetischen Kopplung Zwischen Starkstrom—Hochspannungs — und Fernmeldeleitungen im Stationären Zustand (Contribution to the general theory of e.s. and e.m. coupling between power—H.T.—lines and telephone-lines, in the stationary condition).—G. Eggeling. (*E.N.T.*, August, 1928, V. 5, pp. 312–333.)

A mathematical treatment in which the e.m. and e.s. couplings are dealt with simultaneously instead of separately as has been done by previous writers. A bibliography of 18 items is appended, and in addition the author particularly mentions the report of the Railroad Commission of the State of California entitled "Inductive Interference between Power and Communication Circuits." No special mention is made in the present paper of the importance of the question from the point of view of radio communication.

Störungen von Rundfunkempfang durch Quecksilberdampf-Gleichrichter (Interference with Broadcast Reception due to Mercury-vapour Rectifiers).—K. Heinrich, (*E.T.Z.*, 30th August, 1928, pp. 1296–1297.)

The interference complained of was of two kinds—a strong hum and a weaker whistling noise—the latter unconnected with the frequency of the current being rectified. Research led to the conclusion that the rectifier, in the production of this latter noise, was functioning as an arc generator. A 90,000 cm. capacity across the overhead lines removed this interference, but two microfarads were needed to abolish the hum.

The Deterioration of Quartz Mercury Vapour Lamps and the Luminescence of Transparent Fused Quartz.—A. E. Gillam and R. A. Morton. (*Phil. Mag.*, December, 1928, V. 6, pp. 1123–1132.)

The conclusions are that there are two factors: a shortening of the spectrum confined to the extreme ultra violet, and a non-selective loss in transmission. The first preponderates for the first 150–200 hours and shows itself as a rapid fall in output. During the subsequent life of the lamp the second plays an increasingly important part. It is suggested that the first effect may be due to the formation of silicon monoxide vapour inside the lamp, and the second may arise from the gradual deposition of a film of opaque elementary silicon. Three types of luminescence phenomena have been observed, but have little or no connection with the deterioration.

ACTIONS DES RAYONS LUMINEUX SUR LE CHLORURE DE POTASSIUM (Action of Light Rays on Chloride of Potassium).—J. Risler and F. de Courmelles. (*Génie Civil*, 1st December, 1928, V. 93, p. 535.)

The specific rôle played by potassium in the automatism of cardiac action has been studied by Zwardemaker, who showed for the first time the variations of this element with the seasons. Looking for the causes of these variations, the writers have found that the microradioactivity of potassium chloride is increased by light, which also explains the particularly active part played by the element in the growth of plants.

AN ATTEMPT TO ADD AN ELECTRON TO THE NUCLEUS OF AN ATOM.—W. D. Harkins and W. B. Kay. (*Phys. Review*, June, 1928, V. 31, pp. 940–945.)

Electrons with a velocity corresponding to 138–145 kV. were made to strike the surface of liquid mercury; after a time, this mercury was tested for traces of gold. The absence of positive result suggests that either less than one in a billion of the electrons attached itself to an atom nucleus, or else all or a part of the nuclei produced were not sufficiently stable to endure for the 24–28 hours of the test.

ON NUCLEAR DERIVATIVES AND THE LETHAL ACTION OF ULTRA-VIOLET LIGHT.—F. L. Gates. (*Science*, 16th November, 1928, V. 68, pp. 479–480.)

A letter, from the Rockefeller Medical Research Institute, on the mechanism of the bactericidal action of ultra-violet light.

IMPULSE CHARACTERISTICS OF DRIVEN GROUNDS.—H. M. Towne. (*Gen. Elec. Review*, November, 1928, V. 31, pp. 605–609.)

Cathode-ray oscillograph tests of the behaviour of galvanised iron pipes driven into the soil to form lightning conductor earths.

SPARK IGNITION.—E. Taylor Jones. (*Phil. Mag.*, December, 1928, V. 6, pp. 1090–1103.)

"In the opinion of the writer the thermal theory is the only theory which is capable of accounting for the known facts of spark ignition, and it is hoped that the evidence produced in the present communication will tend to renew confidence in it."

L'ENERGIE THERMIQUE DE L'EAU DES RÉGIONS POLAIRES (The Thermal Energy of the Water of the Polar Regions).—H. Barjot. (*Génie Civil*, 15th December, 1928, V. 93, p. 590.)

The writer proposes to use the difference in temperature between the water beneath the ice (which, protected by up to 5 metres of ice, remains round about zero) and the air, which may be as low as −40 deg., to drive an engine using as fluid one of the volatile hydrocarbons: thus doing for cold regions what Claude and Boucherot propose to do for tropical regions (*cf.* Abstracts, 1928, V. 5, p. 471).

PROTECTION OF ELECTRICAL APPARATUS AGAINST INTERNAL SHORT CIRCUIT. (French Patent No. 646,196, *Comp. Gén. d'Élec.*, published 8th November, 1928.)

The observed fact, that an appreciable time before the breakdown there occurs a diminution of insulation enough to be detected by a suitable arrangement, is here used to give warning or to put the machine automatically out of action.

ZUM UHRVERGLEICH AUF DRAHTLOSEM WEGE NACH DER KOINZIDENZHÖRMETHODE (Time Checking by Wireless on the Aural Method of Coincidence).—H. Martin. (*Zeitschr. f. Geophys.*, No. 2, 1928, V. 4, pp. 53–58.)

For use where recording methods are impracticable, the writer describes a telephonic method accurate to a few thousandths of a second.

THE CIRCULATION OF SEISMOLOGICAL INFORMATION BY WIRELESS TELEGRAPHY. (*Nature*, 26th January, 1929, V. 123, pp. 148–149.)

Supplementing an article (*ibid.*, 22nd December, 1928, p. 968) on the arrangements for broadcasting early information, this article shows the successful correlation, for the large earthquake of 13th January, of data supplied by Kew, Helwan, Bombay, Stonyhurst (by post), Georgetown, Honolulu and Strasbourg. The intersections of the various arcs almost met at a point in the Sea of Okhotsk. The initial impulse measured by the Kew seismographs (three components) indicated a point close to this.

THE EFFECT OF MOIST AIR ON THE RESISTANCE OF PENCIL LINES.—J. B. Seth, C. Anand and G. Chand. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, pp. 29–35.)

The resistance of a pencil line is found to increase when it is kept in a moist atmosphere. In the discussion following the paper, it was pointed out that this effect of humidity on carbon granules is closely connected with their tendency to packing in microphones, particularly those used in certain aural aids for the deaf, which are extremely sensitive to changes of humidity.

NOTE SUR L'ÉLIMINATION DES PERTURBATIONS CAUSÉES PAR LES LIGNES EXPLOITÉES AU MOYEN DE L'APPAREIL BAUDOT (Note on the Elimination of the Disturbances caused by Lines using the Baudot System).—E. Boyer. (*Ann. des P.T.T.*, October, 1928, V. 17, pp. 864–872.)

Disturbances on telephone and radio-telephone circuits were produced by very highly damped H.F. currents caused by the Baudot apparatus. They were cured by the use of suitable filters on the Baudot lines.

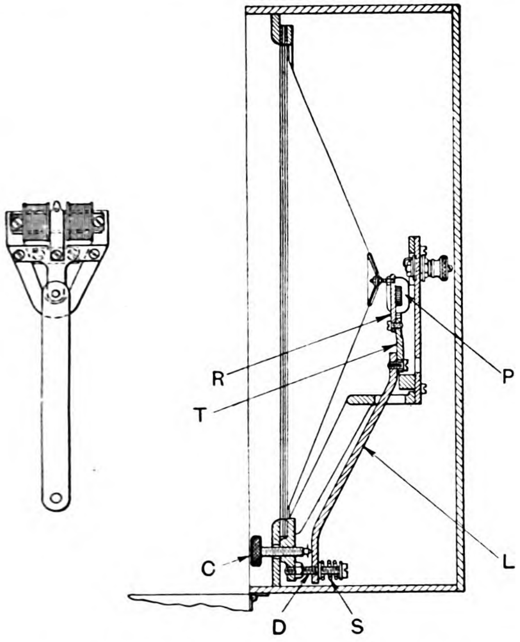
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

CONE LOUD SPEAKERS.

(*Application date, 19th October,* 1927. *No.* 300761.)

The adjustment screw for controlling the air-gap between the magnet and its armature or reed is arranged to be operated from the front of the speaker instead of from behind the instrument as usual. The reed *R* is supported between the magnet pole pieces *P* (only one of which is shown) by an adjustable T-shaped member *T*. Attached to the vertical limb of the member *T* is the adjusting lever *L*, which is brought forward, roughly parallel to the conical surface of the diaphragm, and anchored to a pin *D* rigidly fixed to the rim mounting. The lever *L* is moved to and fro against the action of a spiral spring *S* by a thumbscrew *C*, thereby adjusting the effective air-gap between the magnet and the reed driving the conical diaphragm.



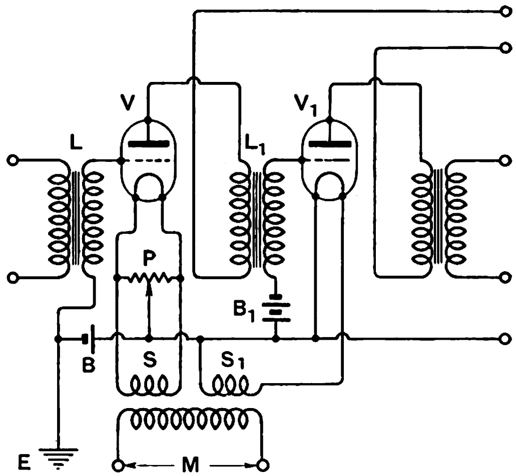
Patent issued to S. G. Brown, F.R.S.

A.C. FILAMENT SUPPLY.

(*Application date, 4th August,* 1927. No. 299908.)

The filament supply is taken direct from a raw A.C. supply so that the filament voltage fluctuates with that of the mains, but the resultant hum from one valve stage is balanced against that due to a preceding or succeeding stage in such a manner that all disturbance in the final output from the amplifier is substantially eliminated.

The mains transformer *M* has two secondary windings *S*, S_1 supplying the filaments of two successive valve stages *V*, V_1. The input winding *L* of the first valve is earthed at *E*, the grid circuit being completed through a biasing battery *B* to an adjustable tapping *P* on a potentiometer shunted across the filament terminals of that valve. The input winding L_1 of the second valve V_1 is connected through a biasing battery B_1 directly to the filament as shown. By suitably adjusting the tapping point *P*, the hum produced by the first valve is fed to the second valve in such phase and magnitude as to neutralise the effect of the direct hum produced by the latter valve, leaving the final output free from noise.



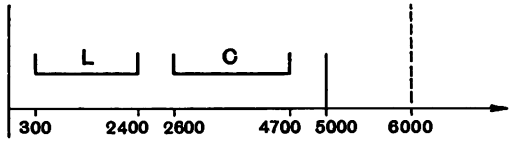
Patent issued to De W. Clinton Tanner.

WIRED WIRELESS WORKING.

Convention date (Germany), 27th May, 1927. *No.* 291110.

In wired-wireless working, different messages are transmitted simultaneously over the same wire by modulating two or more sub-frequencies. The present invention relates to a method of simultaneously combining an ordinary or low-frequency telephone message with a high-frequency or modulated carrier message. In the ordinary way this is not possible, because for high-frequency or carrier-wave working the line is pupinized or loaded to prevent attenuation. The cut-off frequency is then so high as to make the line practically useless for ordinary telephonic speech.

According to the invention this difficulty is overcome by taking a lightly-loaded line having a limiting frequency of say 6,000 cycles per second, utilising a carrier-frequency some 20 per cent. below the cut-off say 5,000 a second, and, after modulation, eliminating the upper side-bands, and preferably the carrier-frequency also, so that the effective message-carrying frequencies are spaced apart as shown in the Figure. Ordinary speech is



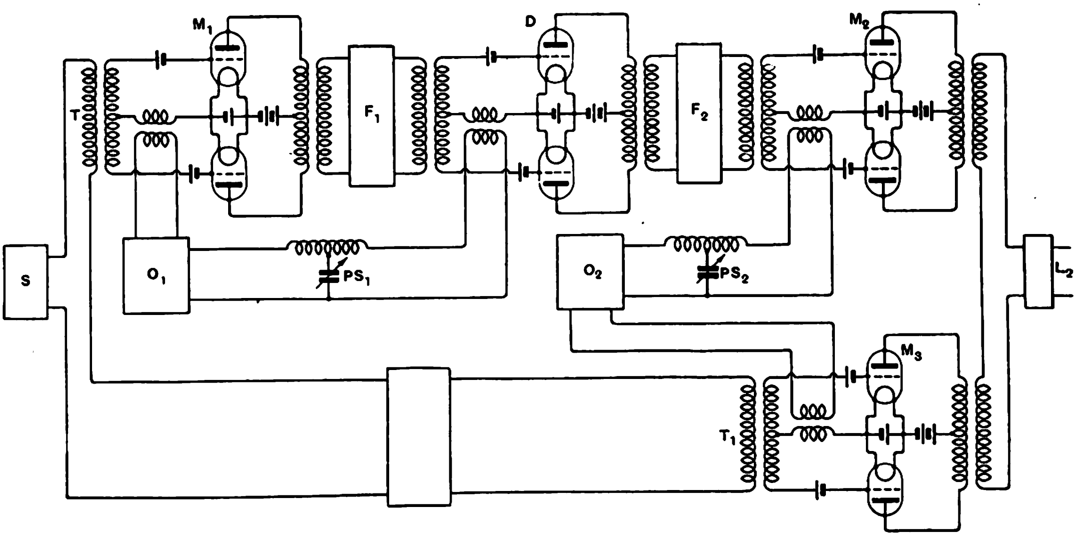
represented by the band L extending between 300 and 2,400 cycles, whilst the lower side-bands C of the high-frequency message range between 2,600 and 4,700 cycles. The original carrier is shown at 5,000 cycles, whilst the dotted line represents the cut-off frequency of the loaded line.

Patent issued to Siemens & Halske A.G.

SINGLE SIDE-BAND SIGNALLING.

(*Application date, 27th August*, 1927. *No.* 301352.)

The difficulty of separating-out one side-band from a modulated carrier wave by filtering-means increases with the frequency of the carrier. For instance to produce single side-band transmission with a carrier of 1,000 kilocycles, it is usual to build up the frequency in two or more stages of modulation, and to use filters at each stage to eliminate the unwanted side-bands.



The invention provides an improved system in which the modulating current is split into two components, differing in phase by 90 degrees. These are then impressed along separate channels on balanced modulating-valves in such a way that the undesired side-bands produced in each instance by modulation are of opposite phase and therefore cancel out, whilst the desired side-bands are combined additively.

As shown, signals from a source S are fed to a balanced modulator M_1 through a transformer T, and simultaneously through a transformer T_1 to a second modulator M_3 located in a parallel channel to the first. An intermediate carrier frequency is supplied to modulator M_1 from a source o_1, which also supplies current of the same frequency, but dephased 90 degrees by a phase-shifter PS_1, to a demodulator D. A filter F_1 passes one side-band of the modulated carrier, whilst the rectified output passes through a low-pass filter F_2 to a subsequent balanced modulator M_2. Currents of the final carrier frequency are supplied from a source o_2, (a) through a 90 degree phase-shifter PS_2 to the modulator M_2, and (*b*) directly to the modulator M_3 in the parallel channel. The final output, which is fed to a line L_2 or to a transmitting aerial, contains only the desired side-band and signal components.

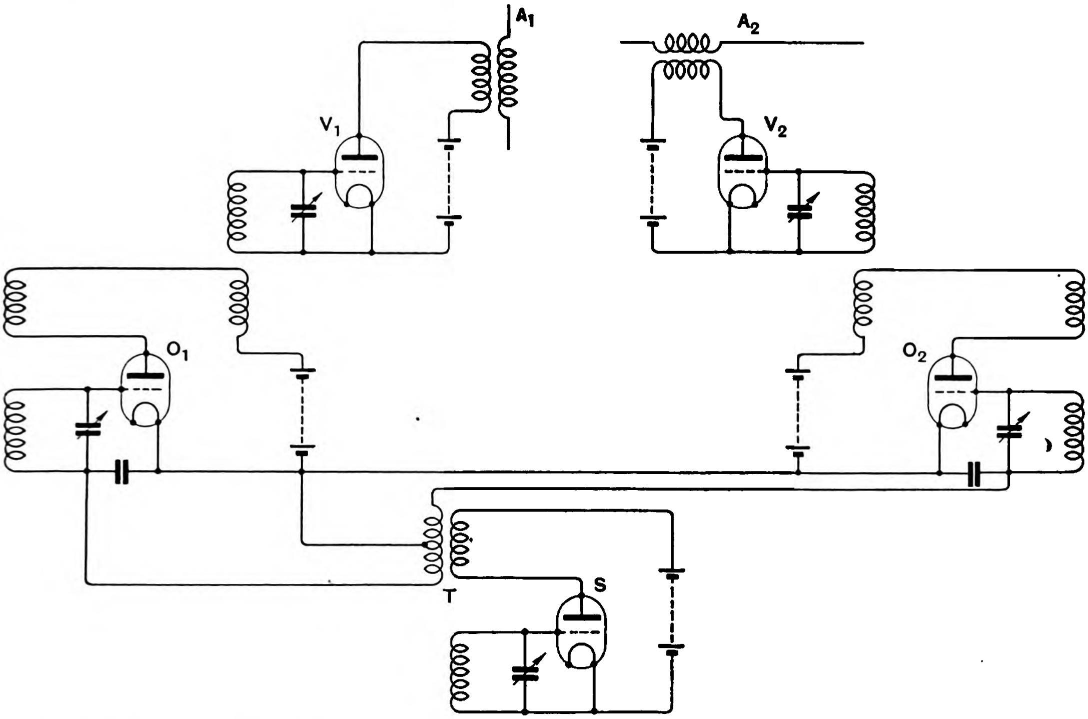
Patent issued to Standard Telephones and Cables, Ltd.

"DOVETAILED" WIRELESS TRANSMISSION.

(*Application date, 27th May*, 1927. *No.* 301436.)

Two or more sets of waves, or modulations, are used, differing either in frequency or in some other characteristic. Transmission is effected by shifting from one wave or modulation to the other at a definite frequency. For instance, the oscillator o_1 generates waves of one frequency, which are amplified by a valve V_1 coupled to the aerial A_1. A second oscillator o_2 generates waves at another frequency, these being fed to an amplifier V_2 coupled to aerial A_2 set in a different plane to the first.

A "shift" valve S oscillates at a relatively low frequency, and is so coupled to the grids of the oscillators o_1, o_2 through a tapped transformer T that it throws them into and out of action alternately.



In reception two aerials are used, each tuned to one of the transmission frequencies. These feed separate valves, the outputs from which are fed to a final combining-circuit in such fashion that signal effects occurring simultaneously in both aerials are balanced out. However by tuning the "combining" circuit to the "shift" frequency of the valve S, the final response can be made dependent solely upon the signal effects occurring alternately in the separately-tuned aerials. In this way the dove-tailed transmission is analysed into its original components. Single or multiplex signalling can be similarly effected, reception being free from either mutual or extraneous interference.

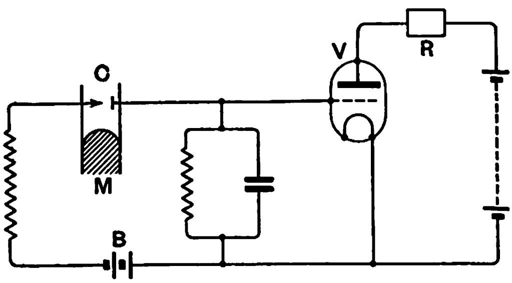
Patent issued to J. Robinson.

TIMING-DEVICES FOR PICTURE-TRANSMISSION SYSTEMS.

(*Application date, 27th July,* 1927. *No.* 301414.)

Timing-devices used in picture telegraphy usually depend upon the action of a master control, such as a tuning-fork, the periodicity of which is liable to be affected by variations of temperature. It is therefore enclosed in a casing which is maintained at a constant temperature by means of a suitable thermostat.

The invention is directed to this object. A mercury-toluene thermometer is used, the expansion of the toluene forcing the mercury column M up along the tube until it bridges a pair of contacts C inserted in the grid circuit of the valve V. Under normal conditions, a relay R in the plate circuit of the valve is kept closed to energise the heating-coil for the casing containing the master frequency-control (not shown). Should the temperature rise too high, the mercury M closes the gap C. This applies a high negative grid bias from the battery B, and so cuts down the plate current



whereupon the relay R opens and cuts off the current supply to the heating-coil. As the temperature falls again to its normal value, the contacts C are broken and the heating coil is replaced in circuit.

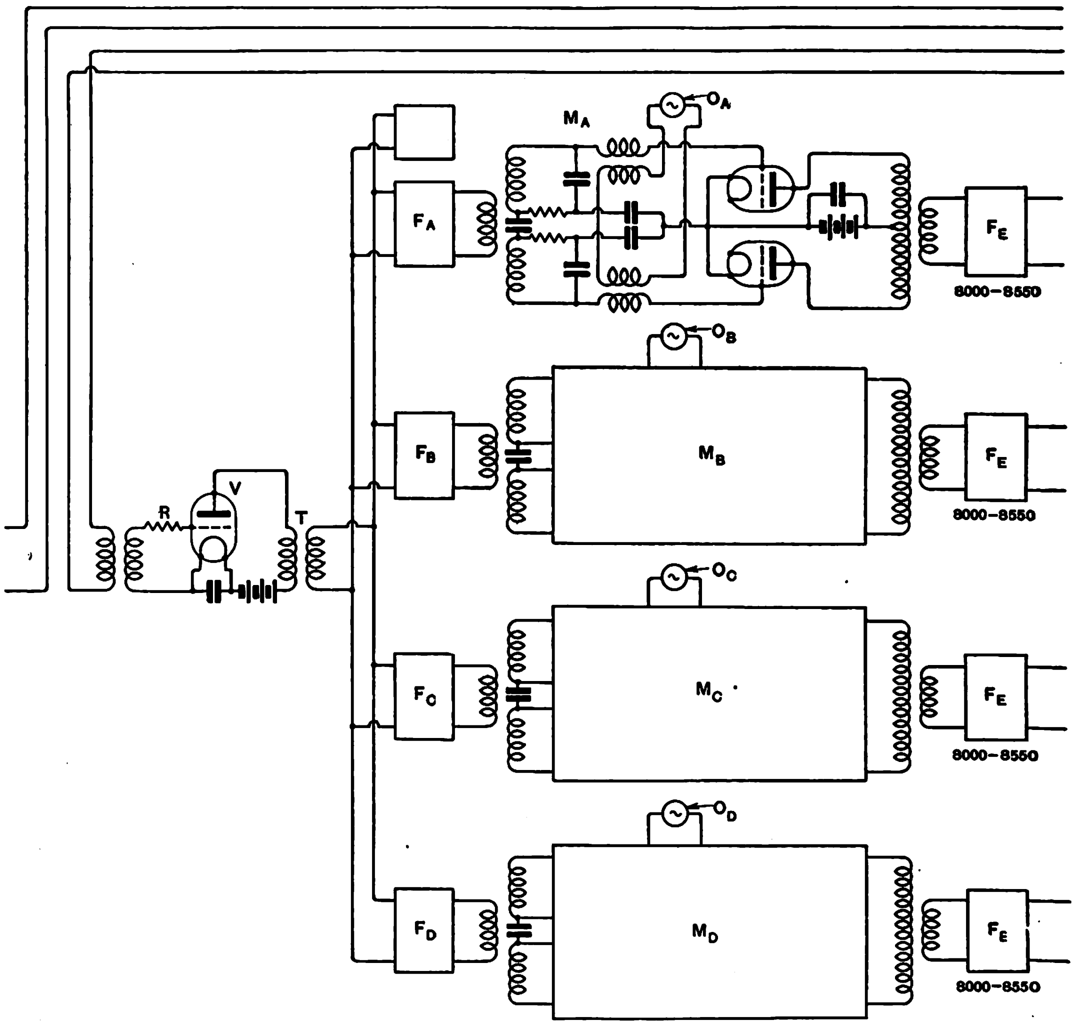
Patent issued to G. M. Wright.

SECRET TELEPHONY SYSTEMS.

(*Application date, 5th August,* 1927. *No.* 299915.)

Signals are applied to an amplifier *V* having a high resistance *R* in the grid circuit to serve as a voltage limiting device. The output is connected through a transformer *T* to band filters F_A, F_B, F_C, F_D which divide the speech band into four equal frequency ranges, viz., 400–950, 950–1,500, 1,500–2,050, and 2,050–2,600 cycles. Balanced modulators M_A, M_B, M_C, M_D, co-operating with local oscillators O_A, O_B, O_C, O_D having frequencies of 7,600, 7,050, 6,500 and 5,950 cycles respectively, (*a*) eliminate the carrier frequency, and (*b*) reduce the sub-bands to the same frequency level, and pass the output through the filter circuits F_E as shown.

The output from the last filters are then connected to the armatures of a number of relays, preferably four for each channel, which are in turn controlled by a number of keys (not shown) in such a way as to reorganise the original frequencies, either by changing their relative position, or by inverting the frequencies within the sub-bands, or by performing both operations, prior to recombining them on the outgoing line for radiation. The secrecy circuit is essentially a one-way device, so that when used for a complete transmission channel or two-way service, it is necessary to employ either two identical secrecy circuits. Alternatively transmission in both directions can be effected by transferring a single secrecy circuit from one line to another by suitable voice-operated or similar relays.



Patent issued to Standard Telephone and Cables, Ltd.

EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. MAY, 1929. No. 68.

Editorial.

Positive and Negative Mutual Inductance.

WHEN two circuits are so placed that a current in one causes magnetic flux to link the other, a change of current in one necessarily induces an E.M.F. in the other, and the magnitude of this induced E.M.F. when the current is changing at unit rate is called the coefficient of mutual induction, or more briefly, the mutual inductance, between the two circuits. By simply moving one circuit relatively to the other it is possible to change the direction of the induced E.M.F., so that the mutual inductance reverses its sign, and it becomes necessary in writing down the circuit equations to adopt some convention as to what is to be called a positive and what a negative mutual inductance. We may say at once that so far as the ultimate result of any calculation is concerned it is immaterial which convention one adopts, so long as one adheres strictly to it, but there is something more to be considered than merely obtaining the correct result, as those engaged in teaching quickly realise. The conventions adopted should always be those which lead to the greatest economy of mental effort in following the various processes represented by our symbols. One could adopt the convention that an applied E.M.F. always produces a current in the opposite direction, and with much justification in the light of our present knowledge, but it would not tend to simplify the consideration of circuit problems. It is our general experience that articles written by those engaged in teaching are easier to follow than those written by those engaged solely on research work; this is only to be expected, since the obtaining of results to one's own satisfaction is a very different matter to the clear presentation of these results to others.

In electric circuit problems it is necessary to decide which direction around the circuit is to be taken as positive and which as negative. If there is only one circuit, it is quite immaterial which direction is adopted, and this is also the case where there are several circuits, although in the latter case considerations of similarity will often influence one's choice. In a plane network, for example, one would preferably decide that the positive direction in every mesh should be, say, counter-clockwise, rather than clockwise in some and counter-clockwise in others. Having decided upon the direction of current around every circuit which is to be regarded as positive, it is reasonable to regard the direction of the magnetic flux through the circuit produced by positive current as the positive direction of the flux. The opposite convention would lead to the inelegant assumption that a positive current produces a negative magnetic flux. Now comes the question: if a positive current in

one circuit produces a positive magnetic flux through another circuit, is the mutual inductance between them to be called positive or negative? Surely positive, but unfortunately one finds that, although this is the usual convention, several important papers have been published in which the opposite convention has been assumed, to the bewilderment of the reader accustomed to the ordinary convention. It seems unreasonable, and it is certainly inelegant, to suggest that, when a positive current in one circuit produces a positive magnetic flux through another circuit, we should call the mutual inductance negative.

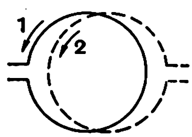


Fig. 1*a*.

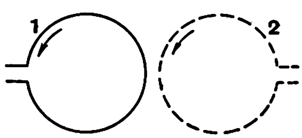


Fig. 1*b*.

To take a simple example, let two single-turn coils 1 and 2 be placed one on top of the other as in Fig. 1*a*, or one beside the other as in Fig. 1*b*. We decide to take the anti-clockwise direction around the circuits as positive. In Fig. 1*a* a positive current in coil 2 produces a positive magnetic flux through coil 1, *i.e.*, a flux towards us, whereas in Fig. 1*b* a positive current in coil 2 produces a negative flux through coil 1. We maintain then that with the convention adopted as to currents, the mutual inductance should be called positive in Fig. 1*a* and negative in Fig. 1*b*. If one possesses the type of mind which decides to call clockwise currents positive in coil 1 and negative in coil 2, then a positive current in one coil in Fig. 1*a* will produce a negative flux through the other and the mutual inductance should then, we maintain, be regarded as negative in Fig. 1*a* and positive in Fig. 1*b*.

When an E.M.F. e acts on a non-inductive circuit of resistance R, we have $i = e/R$; if the circuit has a self-inductance L and the current is changing, the resultant E.M.F. acting in the circuit is $e - Ldi/dt$ and we have $i = \dfrac{e - Ldi/dt}{R}$ or $e = iR + Ldi/dt$. The self-inductance L is assumed to be an essentially positive quantity and the induced E.M.F. is of opposite sign to di/dt. If now there is another circuit in which an increase of current causes an induced E.M.F. in the first circuit in the same direction as would be caused by an increase of current in the first circuit itself—which is only another way of saying that a positive current in the second circuit produces a positive flux in the first circuit—then we maintain that M should be regarded as positive, so that if i_1 and i_2 are both increasing the effects of mutual inductance are in the same direction as the effects of self-induction and are added to them. This gives the equation

$$e_1 = i_1R_1 + L_1\frac{di_1}{dt} + M\frac{di_2}{dt}.$$

It is to be particularly noted that this is true whatever convention one has adopted as to the positive direction of currents in the circuits. If, however, having adopted a given convention as to the directions to be called positive, one then says that a mutual inductance is to be called negative when a positive current in one circuit produces a positive flux in the other circuit, then the above equation would have to be written

$$e_1 = i_1R_1 + L_1\frac{di_1}{dt} - M\frac{di_2}{dt}.$$

This note is written as a protest against this latter form of the convention.

As an example of the peculiar results obtained by those who adopt this unfortunate procedure, we may consider the case of a coil or solenoid tapped at some intermediate point. If the self-inductances of the two parts considered separately are L_1 and L_2, then instead of the inductance of the whole coil being given by the formula $L = L_1 + L_2 + 2M$ where M is the mutual inductance between the two parts, they are forced to write $L = L_1 + L_2 - 2M$. In this case the effects of mutual inductance are so obviously of the same nature and sign as the effects of self-inductance that it seems very unreasonable to adopt a convention which makes the mutual inductance negative whereas the self-inductance is regarded as essentially positive.

French System of Directional Aerials for Transmission on Short Waves.

By H. Chireix.

(Chief Engineer of the Société Française Radio-Electrique.)

THE object of this article is to describe the French system of aerials for transmission by short projected waves such as was achieved by the author at the beginning of 1926, and as is now employed by the Société Française Radio-Electrique in its installations in France and foreign countries.

Theoretical Considerations Recalled.

In a now somewhat old article in "Radio-électricité" (Bulletin Technique of the 25th of July, 1924) the author dealt with the question of directive aerials from a theoretical standpoint, and discussed the diagrams as well as the various practicable combinations of aerial alignments.

This discussion may be recapitulated as follows:—

(1) If vertical aerials are placed in line at equidistant spots, the distance being less

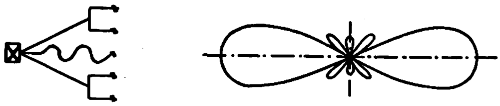


Fig. 1.

than one half-wave length, and if these carry currents of equal value and phase (type 1), the diagram of the resulting field obtained in the horizontal plane will have the form of Fig. 1, that is to say, a sharpened "8" together with small symmetrical loops. The maximum radiation takes place in the two directions perpendicular to the line of aerials, and the greater the developed length of the line the more the principal "8" is sharpened, the greater is the increase in the number of small loops, but the more the importance of these loops is diminished. This case corresponds, in fact, to the limiting case of a parabolic reflector of cylindrical form whose double focus is situated at infinity. (2) If vertical aerials are placed in a row at equal distances, the distance between each being less than one half-wave length, and if these carry currents of equal value but out of phase by a quantity corresponding to the speed of propagation of electromagnetic waves in air, that is, 180 deg.

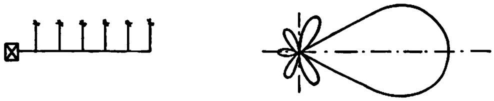


Fig. 2.

for each half-wave length (type 2), the resulting diagram in the horizontal plane will have the form shown in Fig. 2, that is to say, of a cardioid together with small loops.

The maximum radiation takes place along the direction of the aerials and in the direction of the phase-lag. In the other direction the radiation is, on the other hand, very much reduced. The greater the length of the row the more the principal part will become sharp, and the more the number of small loops will increase while their size will diminish.

This type of alignment corresponds to the limited case of a cylindrical parabola whose focal distance is zero (an infinitely flattened parabola).

(3) If nevertheless a comparison be made between these two types of alignment, it is found that the alignments of type 1 produce

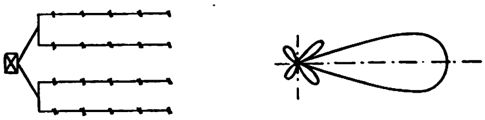


Fig. 3.

very rapidly, that is to say for a moderately developed length, a very sharp diagram, but that they project equally well the energy in two diametrically opposite directions. On the contrary, the alignments of type 2, for a like developed length, give a much broader diagram, but possess the valuable quality of radiating the energy in one direc-

tion only, even if they are reduced to two aerials situated at a suitable distance apart.

(4) If finally there be combined, according to Fig. 3, suitable parallel and perpendicular alignments such as those of Figs. 1 and 2, we get the advantage of the characteristic features of each of the two types, and thus obtain in the horizontal plane a general diagram which is at the same time sharp and has but a single direction.

In 1924 the author made special experiments with the system shown in Fig. 3, based upon these theoretical considerations.

In order to have the entire diagram, that is to say in the space of three dimensions, it is necessary to take account of the directivity of the system in the zenithal plane, this latter directivity being due on the one hand to the proper directivity of the individual aerials in this plane, and on the other hand to their grouping.

Thus, if in the case of the alignments of type 2 the phase displacement between two consecutive aerials is less than that which corresponds, for their spacing, to the speed of propagation of electromagnetic waves in the air (*i.e.*, below 180 deg. for a spacing of one half-wave length), the maximum radiation will take place for a direction

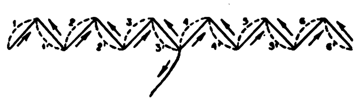


Fig. 4.

which is inclined with reference to the ground, whereas each individual aerial of the group will have its maximum radiation in the direction of the ground.

Principle of Construction.

In view of these theoretical considerations which will obviously prevail whether currents are brought by power lines or electromagnetically induced, the author undertook to realise in as simple a manner as possible, both from an electrical and a mechanical standpoint, a wave-projecting device adapted both for transmission and reception, and having the following essential features, viz., a sufficiently sharp one-way diagram in the horizontal plane, and only moderately so in the zenithal plane, and projecting or receiving energy along the direction of the ground, or at will, in a direction which is very slightly inclined from the ground.

According to what precedes, these conditions can be realised by constituting two identical alignments or rows, one behind the other. The aerials opposite one another

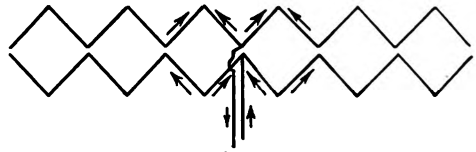


Fig. 5.

will form a row of the second type. In the following description one of the rows will be termed antenna and the other reflector or screen. Since the two rows are identical, either one can obviously serve as an antenna or as a reflector, according to the direction in which the energy is to be transmitted or received. In what follows we shall consider mainly the case of transmission, although the developments and results apply equally as well to the case of reception.

Let us consider a wire developed in zigzag (Fig. 4) with right angles or elbows, and supplied for example at the middle by a feeding wire. If the length of each strand is regulated approximately to a half-wave length, and if the whole device is the seat of stationary waves, the amplitude and instantaneous direction of the current may be shown by the curves and arrows represented on the figure. It will be observed that the aerials 1—2—3—4—5—6 form the first row of half-wave aerials in phase and separated by a half-wave length, and that the aerials 1′—2′—3′—4′—5′—6′ constitute a second row of half-wave aerials also in phase between them, but their common phase is in opposition to the common phase of the first row.

The field produced at a distance by each row is separately calculated, and it leads to a diagram of the type shown in Fig. 1. Since the two rows *are crossed at right angles*, the field due to the vector comprising the two fields, which are equal and at right angles, will be at all points equal to $\sqrt{2}$ times the field due to one row. That is, the diagram due to the combined action of the two crossed rows will still be of the type shown in Fig. 1. It will be readily observed that if the general direction of the wire is

horizontal the resulting electric field will be vertically polarised, as in a vertical antenna. By turning the whole system by $\pi/2$ we evidently obtain a horizontal polarisation. Again, since the several unit elements are of half-wave lengths, the maximum radiation will take place perpendicularly to the plane of the wires, that is to say, horizontally.

This arrangement is of a very simple character and is quite effective in practice. The angles or elbows of the wire coincide with the nodes of the current, and will not cause any reflection of the energy, so that the maximum current will only diminish very gradually from the centre to the ends.

If the system shown in Fig. 4 is doubled as shown in Fig. 5, it will be seen that if the two power supply wires are, for two opposite points, the seat of equal and opposite potentials (Lecher wires), in the first place the feeding line will not radiate energy (the instantaneous currents being in an opposite direction on the two wires), and in the second place, it will be observed (according to the direction of the arrows showing the instantaneous direction of the currents) that the effects of the second system will be added to those of the first system. The whole is now the equivalent of *two rows crossed at right angles*, of unit aerials constituted by two *half-waves in the same direction*. The maximum radiation will thus remain perpendicular to the

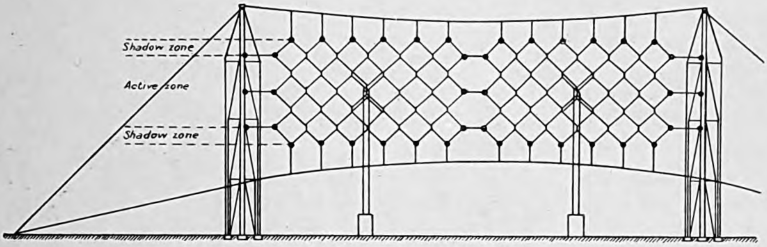


Fig. 6.

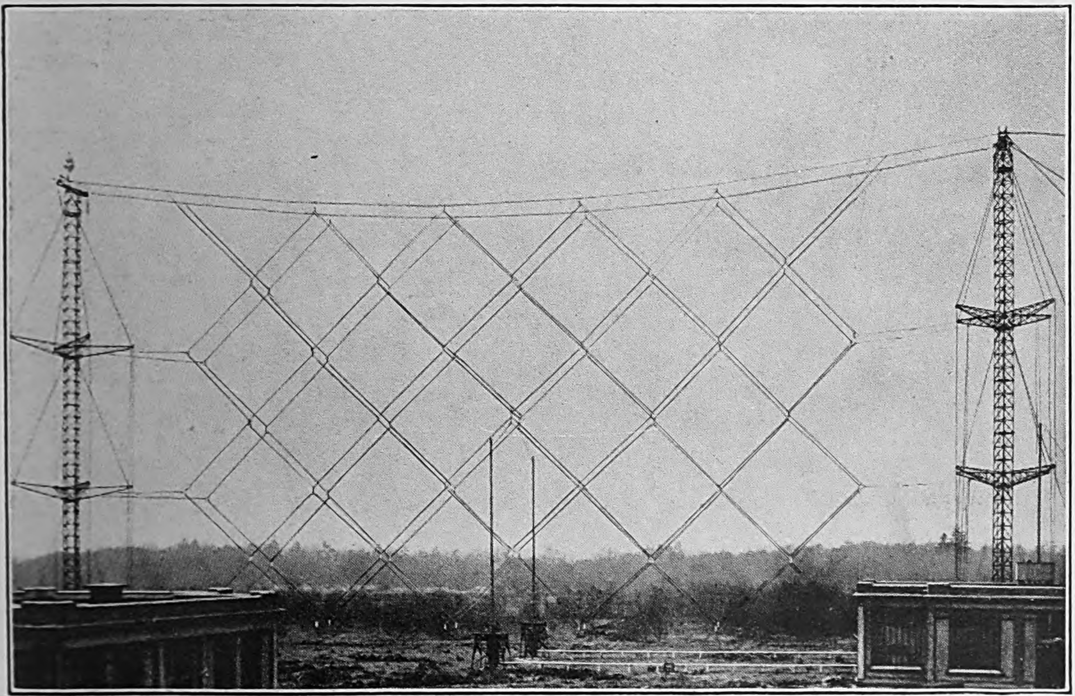


Fig 6(a).

cular to the plane of the wires; that is, the maximum energy is radiated in a direction parallel to the ground.

The reflector, of identical construction, is placed at about $\frac{1}{4}$-wave length in the rear of the aerial, and in normal conditions it is not supplied with current. The feeding lines of the reflector instead of being connected to the transmitter are simply short-circuited at a suitable spot, so as to obtain the "general tuning" of the reflector. This tuning consists in exciting in the reflector currents which are leading by $\pi/2$ in advance to the antenna currents. It is easy to verify this by observing that the *back field* is almost entirely absorbed, while it is doubled in front, for a given current in the aerial.

The normal projector constructed by the Société Française Radio-Electrique will practically concentrate all the energy in an angle of 8 deg. to 10 deg. on the horizontal plane.

Principal Advantages.

(1) Owing to their construction, either of the two sheets can serve as an aerial or as a screen, and hence the diagram can be

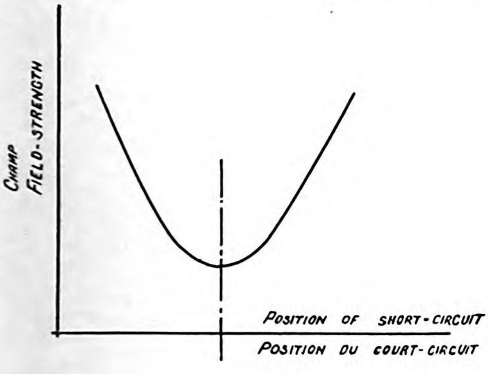


Fig. 7.

readily turned through 180 deg. by suitable switching.

(2) It is an easy matter to tune the screen to the exact wavelength (and to modify this tuning if the wavelength changes) by acting only upon the short-circuiting position of the wires of the screen. Fig. 7 shows the manner in which the back field is modified by the position of the short-circuit. We attain practically the figure 20 for the ratio between the front and back fields.

By slightly modifying this adjustment we may give the beam a slight vertical inclination, as above stated, as we thus change the relative phase of the currents in the aerial and in the reflector.

(3) Similarly, owing to this construction the diagram in the zenithal plane afforded by each sheet will give a maximum effect in the horizontal direction, and this is a very favourable condition, according to tests

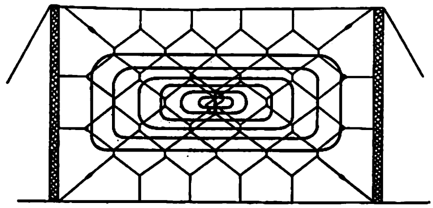


Fig. 8.

made principally by Dr. Meissner both for transmission and for reception (*), which tests show that at great distances it is preferable to transmit and receive energy in a practically horizontal direction.

(4) Due to its construction the system is well adapted also for aerials which are high and are well above the ground, thus raising the whole outfit and particularly the central feeding point. It is, in fact, observed that the mean value of the current in the different elements may be represented by Fig. 8, in which the degree of approach of the full lines gives a certain estimate of the density of the mean current. This density is at the maximum near the centre, and by raising the whole sheet of currents we remove from the ground the whole transmitter or receiver of power. The practical gain obtained in this manner is quite considerable, both for transmission and reception (†).

(5) The fact that when proceeding from the central feeding point the number of half-wave elements is not great, added to the consideration of the damping due to the

* Jahrbuch der drahtlosen Telegraphie und Telephonie, Zeitschrift für Hoch Frequenztechnik, Band 32, Heft 4, von A. Meissner und H. Rothe.

† Remark: The aerial might be constructed for the "day wave" in the form indicated, then using the free space beneath the aerial for a "beam" of reduced value, for the "night wave," as shown in Fig. 8(a). This is justified by the fact that the night wave is used for a shorter time than the day wave, and only in the no-load traffic hours. This arrangement has been adopted in practice for the receiving aerials.

radiation, renders this type of antenna hardly critical as regards the wavelength. In fact, we may allow a total range of 10 to 15 per cent.

For greater changes in the wavelength the apparatus can be readily dismounted and installed.

(6) From a mechanical point of view the plant can be readily constructed, and, on the other hand, since the number of feeding points is now reduced to two, the feeder system is much simplified, as well as the accessory outfit consisting of transforming or coupling boxes, as will be explained later on.

(7) The adjustment is very simple and rapid, since it is limited to the placing in phase of the two sections shown in Fig 6, and to the tuning of the screen. This consideration can well be of great importance, especially in plants in the colonies where skilled or competent persons may be lacking.

Other Constructions.

Figs. 9 and 10 show another arrangement

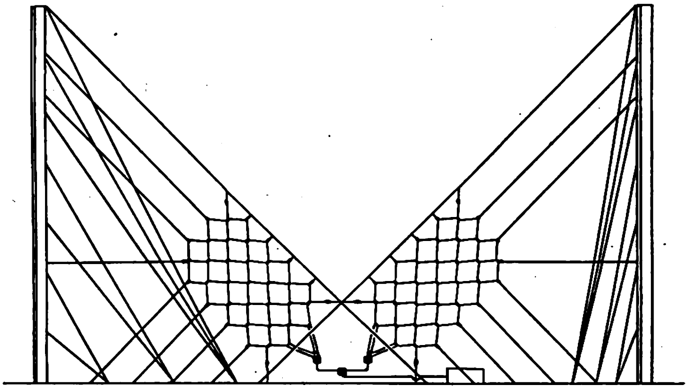


Fig. 9.

which is most advantageous in the case of projectors for short wavelengths to be erected in great centres of transmission

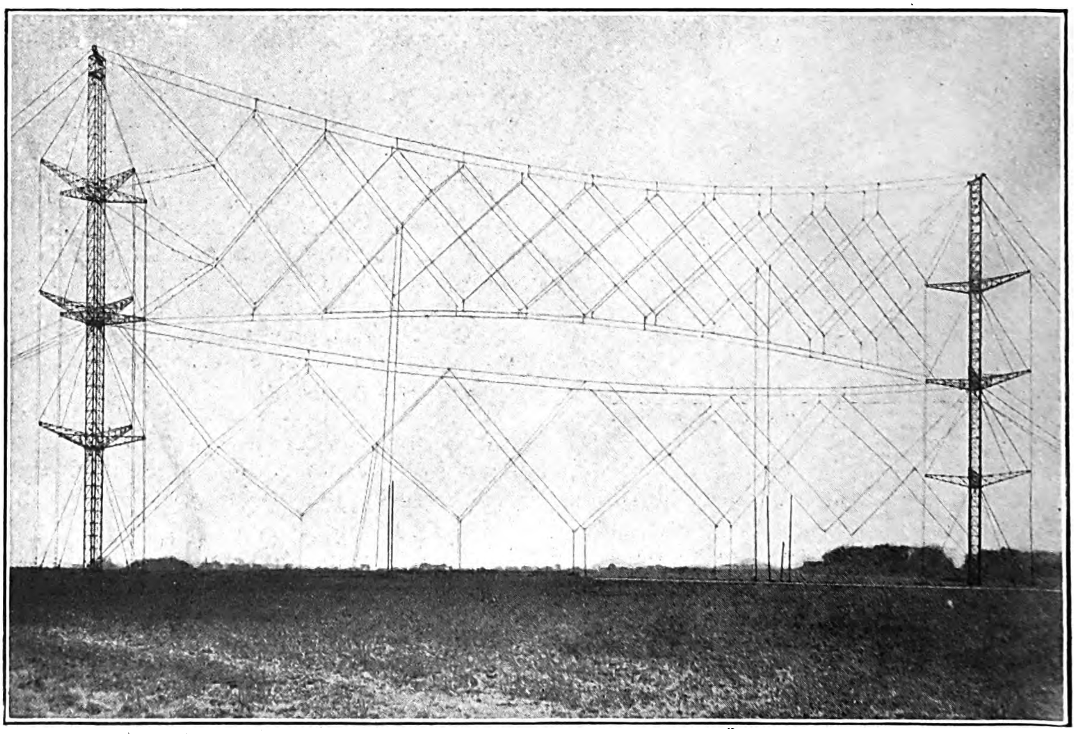


Fig. 8(a).

provided with large aerials with long waves. The towers already erected are used to support the aerials. As shown in Fig. 9, the disposition is practically the same, but the whole plant is rotated by 45 deg., thus rotating to the same degree the plane of polarisation of the electromagnetic field.

Figs. 9 and 10 correspond to an experimental construction for telephone connection between France and Indo-China, and it is observed in Fig. 10, which is a plan view, that the plant comprises two aerials situated in different planes, which was required by the nature of the ground but gave no additional complications, since it is always easy to adjust the relative phases in order to obtain the maximum effect in the desired direction. Fig. 11 shows the diagram of the corresponding field, which is particularly sharp.

Feeders and Transformation Boxes.

Owing to the disposition of the projecting aerials and to the fact that in a great transmitting centre it is necessary to use several aerials for the different receiving stations and the various wavelengths, the feeders must

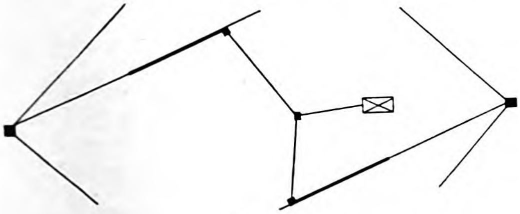


Fig. 10.

often measure several hundred metres in length, that is, a length corresponding to a considerable number of wavelengths. In this case care should be taken that firstly the feeders will not radiate any appreciable amount of energy, which would offer prejudice to the directive properties of the antenna, and, secondly, that there should be a minimum loss in the feeders. These conditions can be fulfilled by using tube feeders comprising two concentric tubes. The current flows forward through the inner tube, which is at a certain potential above earth, and it returns through the outer tube, which is at ground potential. In these conditions the outer tube forms a Faraday cage with reference to the inner field, thus preventing all prejudicial radiation, and, on the other hand, the metal has a large enough surface to afford a low ohmic resistance in spite of

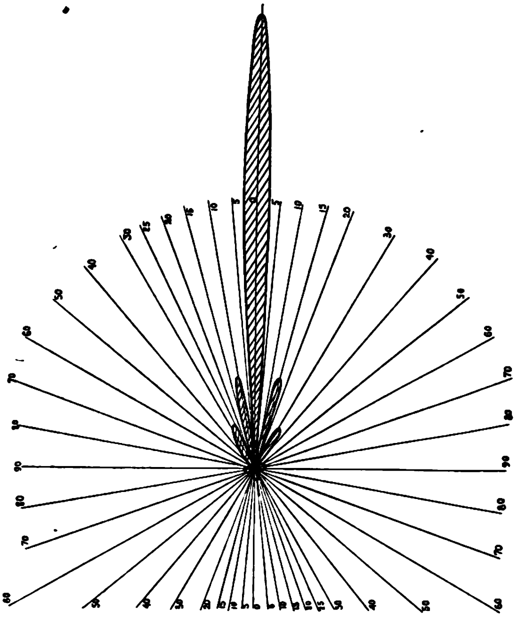


Fig. 11.

the great skin effect at the usual frequencies of projecting aerials.

Since the minimum loss takes place when the feeders carry currents free from stationary waves—that is, when the feeder supplies current at its characteristic impedance—we thus realise this condition. Referring to Fig. 5 or Fig. 6, which represents the arrangement of the wires leading to the central point, it is observed that the two supply wires should possess, in the parts oppositely

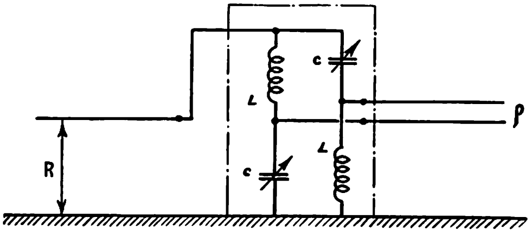


Fig. 12.

placed, potentials which are equal and opposite with reference to the ground. These supply wires also carry stationary waves, as there is no transformer at the

central feeding point. It is thus necessary to place between the output end of the tubular feeder and the input end of the aerial a junction box which serves, firstly, to produce at the input end towards the aerial potentials which are equal and symmetrical with reference to the ground, and, secondly, to extinguish the stationary waves in the tubular feeder. This double condition is realised by the Wheatstone bridge arrangement shown in Figs. 12 and 12(a), which comprises two equal self-inductions and two equal capacities. It can be readily

(*a*) The condition of resonance for the given wave, and (*b*) the additional condition $\frac{L}{C} = R\rho$; otherwise stated, the characteristic impedance of the circuit is made equal to the geometrical mean of the outward and inward impedances. In these conditions it can be easily verified that the stationary waves are extinguished on the upper side—*i.e.*, in the tubular feeder—by disposing in this tube, and opposite suitable sight holes, three ammeters equally spaced (at about $\frac{1}{4}$- or $\frac{1}{3}$-wave length) and by observing

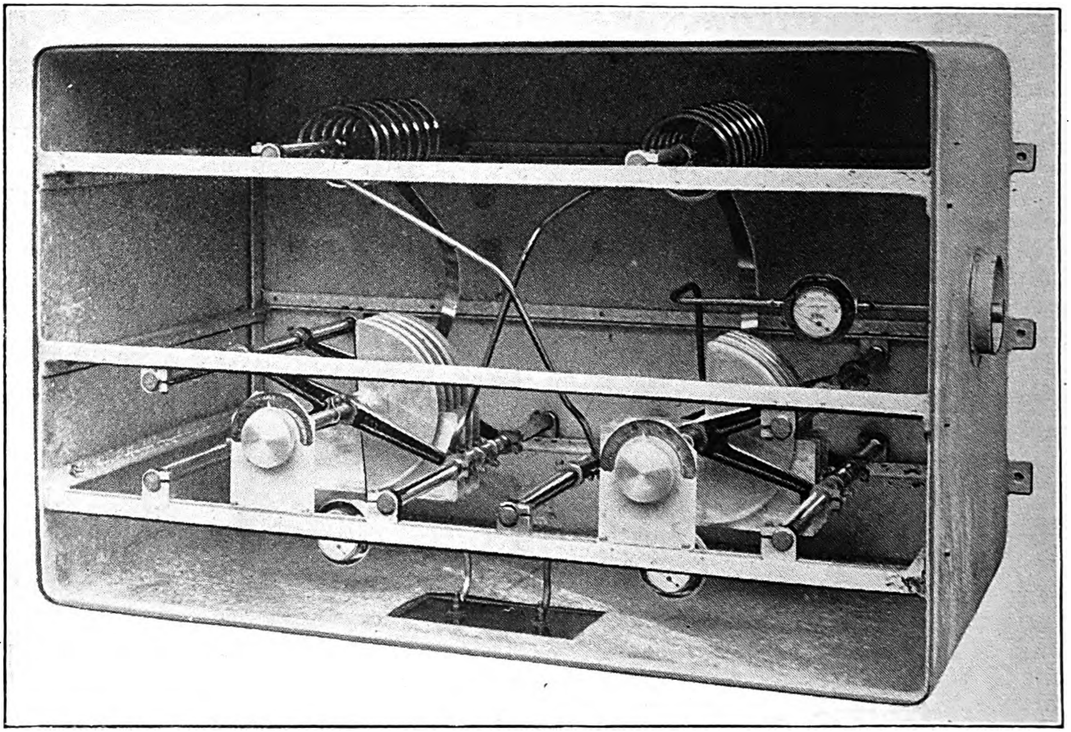


Fig. 12(a).

demonstrated that, if ρ (*) is the characteristic impedance of the tubular feeder and R that of the antenna to be connected, and if the box is placed at a point so that the antenna will represent at this point a pure resistance (that is, a node or an antinode) it can comply with the two conditions in several ways, especially by realising:

* At the frequencies employed, the characteristic impedances become reduced to pure resistances.

the deflections which should then be the same for the three ammeters.

The general diagram of the distribution, starting from the transmitter, and for a two-section aerial, is as follows (Fig. 13).

The output takes place in a tubular feeder (1) as far as a branch box 2, at which the single feeder is divided into two tubular feeders 3 and 4. This box essentially comprises (*a*) a transformer consisting of the self-induction L and the capacity C, which

connects the feeder (1) to the parallel set of feeders (3), (4) of a different characteristic impedence ;

(*b*) An element of "*adjustable line* 1" consisting of a copper worm tube. It is observed

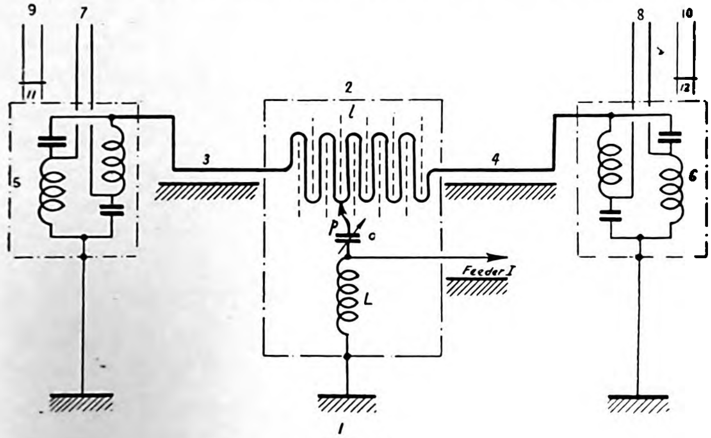


Fig. 13.

that by moving the point *p* to the right, for instance, we reduce the length of the line 4 and increase the length of the line 3, so that we can readily adjust the relative phase of the two sections, this effect being obviously reversed if the point *p* is moved to the left.

The feeders 3 and 4 end at the abovementioned junction boxes 5 and 6, 7 and 8 are now the outputs towards the aerials, 9 and 10 are descents from the screen ; 11 and 12 are the tuning short-circuits of the screen, as already mentioned.

The adjustments are readily made by placing a checking aerial in the direction in which it is wished to transmit, and at some distance to avoid errors due to parallax. If the connections are reversed at 8, the two fields will not be added but will be subtracted, thus producing a zero. It will then suffice to again establish the connections at 8 in their normal direction. We then proceed with the tuning of the reflector by reversing the aerial and reflector, so that the checking aerial will show only a negligible field.

If instead of adjusting the two sections so as to have equal phases we modify the relative phase, the shape of the diagram Fig. 14 can be somewhat changed so as to favour the radiation in a slightly different direction. This may be advantageous for two receiving correspondents such as Rio and Buenos Ayres, which, when considered from Europe, have but a slight difference in direction, and it will suffice to act upon the point *p* so as to favour one correspondent or the other. This operation may be made instantaneously.

Practical Results Obtained.

The first aerial of this type which was put in use was operated at Sainte Assise in January, 1928, for corresponding with South America. At the start it comprised only a single section, mounted on two 39-metre towers, 75 metres apart. This plant could handle the rapid automatic traffic for most of the day, while before this time, the automatic traffic was practically impossible above 30 words per minute (Fig. 15). Although the plant was of a very reduced size, it showed practically the same results in the traffic as the other stations on the "beam" system. It was even possible during the month of March to maintain a permanent connection with Buenos Ayres (which had no receiving beam nor very modern receivers) for the whole 24 hours, on a 15.45 metre wave, simply by changing several times during the night (15 metres is a day wave) the direction in which the waves were sent (reversal of the beam). These reversals, which were requested by Buenos Ayres, served to counteract the *fading* or the *echo effect.*

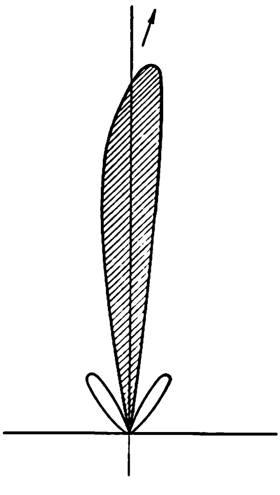


Fig. 14.

The same aerial, used somewhat later as a receiving aerial, afforded to the receiving end the same advantages as the other beam installations.

When the second section was added we were able to verify, according to theory, that the energy radiated in the selected direction for a given power, was now double; in other words, that the field at a distance was multiplied by $\sqrt{2}$.

During the summer of 1928, and to within a recent date, numerous telephony tests were made with Saïgon on the aerials shown in Figs. 9 and 10, in the presence of various official personages.

It is interesting to note in this connection that a beam as narrow as the one shown in the diagram 11, obtained with the two aerials of Figs. 9 and 10, gave better results than the beam of twice the width corresponding to a single aerial in operation. The telephone reception in Indo-China and Siam with a transmitter not exceeding 10 kilowatts on antenna was greatly appreciated as being much stronger than that of the other stations, and particularly the stations operating a telephone service with Java.

Since the beginning of this year public telephone conversations have been exchanged between Paris and Buenos Ayres. The transmitter and receiver on the French side are equipped with projecting aerials of the type described. The fact that it has been possible to open and regularly maintain a public telephone communication between such distant countries shows more than anything else the great technical progress realised during the last years by the use of projecting aerials.

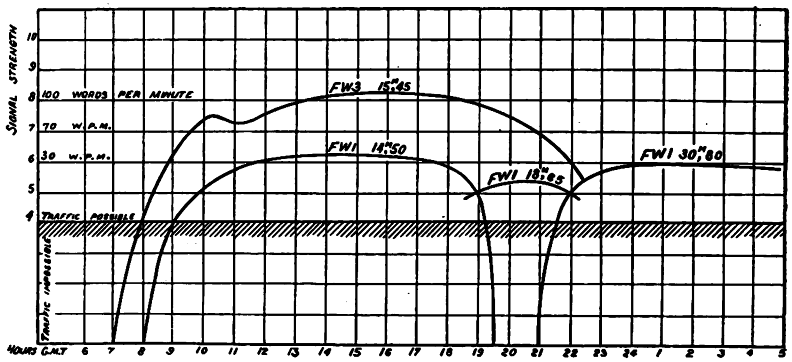


Fig. 15.

Book Reviews.

AN INVESTIGATION OF THE INTERFERENCE CAUSED BY TRANSMISSIONS FROM RADIO STATIONS. Special report No. 8 on Radio Research issued by the Department of Scientific and Industrial Research. Pp. 40+vi. 10 Figs. Pubd. by H.M. Stationery Office. Price 1s.

In the Regulations of the Washington Draft Convention of 1920, it was proposed to classify radio transmitting stations under four headings—viz., A1, keyed C.W.; A2, Tonic Train; A 3, Telephony; B, damped waves, and it was proposed to specify an allowable capacity for interference for each type. The method suggested was based on the assumption that the equivalent decrement of the transmission as determined from a resonance curve was a measure of its capacity for interference. Doubts soon arose as to the correctness of this assumption and in 1923 the matter was submitted to the Radio Research Board. The present report is the result of the investigations carrled out for the Board; it consists of two parts: (1) The measurement of the equivalent decrement of various types of transmissions, by R. L. Smith-Rose and F. M. Colebrook; and (2) The study of the interfering properties of radio transmissions by the latter. The report shows firstly, that the equivalent decrement is not a criterion of the interference and, secondly, that it appears impossible, with the present technique, to devise a method of measurement which would give a proper criterion. What is required is a complete spectrum analysis of the radiated wave over the whole range of frequencies. Unfortunately, the best of wavemeters responds to a relatively wide band of frequency and defeats one's attempts to take a "narrow sample." This is discussed very ably in the Report, both from a mathematical and experimental point of view, and a bibliography of the various works referred to is added, making the Report a very valuable one to all those interested in this important subject.

By way of criticism, we think that such sentences as "high-speed telegraphy by key controlled amplitude modulation of single frequency waves" and "in the case of a pure tone modulated carrier wave" would be improved by a judicious use of hyphens. The authors seem undecided between "detuning" and "distuning" a circuit, and try both within half-a-dozen lines. There is something wrong with the statement on page 18 that "at a nominal frequency of 15,000 cycles per second at, say, a speed corresponding to 55 words per second (*i.e.*, about 250 complete oscillations to a dot.)" When sending at this speed the duration of a dot would only cover about 15 complete oscillations.

The Establishment of a General Formula for the Inductance of Single-turn Circuits of Any Shape.

By V. I. Bashenoff, Mem. I.R.E., Member of the Russian Society of Radio Engineers.

SUMMARY.—The article contains a brief description of the first part of the author's work in investigating the design and use of closed aerials—namely, on the calculation of the inductance of single-turn circuits of any shape, including curved ones.

The author has derived a general formula and shows that all the well-known formulæ are, practically speaking, special cases of this general law. From the general formula are derived the special formulæ in a new and simplified form.

Numerous tests of the accuracy of this general formula made by practical measurements on closed aerials and other figures, with a height at the point of support of from 2 m. to 65 m., with perimeter from 16 m. to 385 m., with area from 10 m.² to 6,200 m.², have fully confirmed the author's conclusions.

In the May issue of this Journal (Vol. V, No. 56, pp. 259–263) there appeared an interesting article by Mr. Allen, in which the author obtained formulæ for the inductance of a circle, square, rectangle, equilateral triangle and hexagon. The technical editor of this Journal commented in the same number on my article on the subject printed in the December, 1927, issue, of the Proceedings of the Institute of Radio Engineers.

This encourages me to bring before the readers of this Journal a brief description of my recent work in establishing a single formula for the inductance of single-turn circuits of any shape.

This is the more timely since the question of using closed aerials is now regarded as most important (see "J.I.E.E.," VI, 1928, *E.W. & W.E.*, II, 1928, Proc. I.R.E., VII, 1928, etc.).

The investigation referred to below owed its inception to the necessity of finding a formula for the inductance of closed aerials of irregular shape; this forms the first part of the general problem "Calculation of closed aerial" successively solved by the author and his pupils in the State Electrical Research Institute, Moscow.

In 1915 the author made an experimental and theoretical comparison of different receiving factors when using on the one hand frame aerials (with a winding area up to 20 m²) and on the other closed aerials carried from a mast 25 m. high. Similar experiments as regards transmitting factors were made by the author in 1918. He came to the conclusion that closed aerials with a large winding area and small number of turns show most decided advantages in both transmitting and receiving as compared with the ordinary frame aerial with a large number of turns and small winding area.

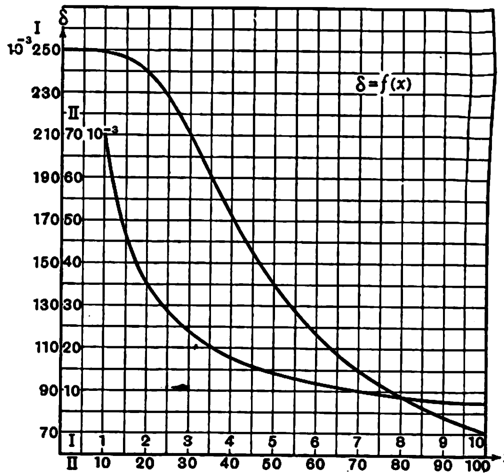


Fig. 1.

This basic principle was applied by the author when building all the wireless stations of his system (more than 40 in number).

Experience showed that owing to economic and other reasons closed aerials supported

from one mast were the most popular. In all the stations built by the author only one mast was used. For further details of the closed aerial system reference should be made

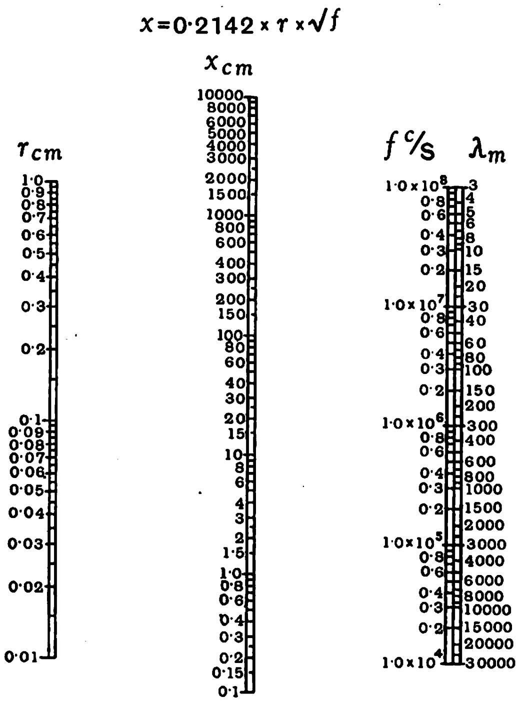


Fig. 2.

to the author's patents: D.R.P., No. 420450 and 430695, U.S.A. Patent No. 1652388 (of 13th December, 1927), Brit. Patent No. 223713, Patent in U.S.S.R., Nos. 353, 3251 and 5261, and other patent applications in other countries.

My formula mentioned by Prof. Howe is:

$$L = 2l\left(\log_e \frac{2l}{r} - a_k + \mu\delta\right) \quad .. \quad (1)$$

where l = the length of wire (the perimeter), r = its radius, μ = permeability and δ is a correction factor depending on the frequency f, which, of course, only modifies the flux within the material of the wire itself; $\delta = 0.25$ for D.C. and low frequencies and decreases as the frequency increases; in general δ is determined as a function of x (see Fig. 1)—which in turn is expressed by

$$x = 0.281\, r\sqrt{\frac{\mu f}{\rho}} \quad .. \quad .. \quad (2)$$

In this formula: f = frequency, ρ = specific resistance of wire in microhms per cm. cube (for copper wire at 20 deg. C, $x = 0.2142\, r\sqrt{f}$ and is found by means of the nomogram, Fig. 2).

As concerns the value of a_k in the formula (1) the author was of the opinion that it must be the same for all figures with equal $l/\sqrt{s}$, *i.e.*, the parameter a_k is a function of this ratio only (s = the area of the circuit). In the above-mentioned work reference is made to the method of finding the value of $a_k = f(l/\sqrt{s})$, graphically shown in Fig. 3.

In the concluding part of the published work a correction was added to Formula 1; this correction $\triangle$ is a function of l/r and is expressed as a percentage addition to the value of L found by formula (1). The values of $\triangle$ are shown on Fig. 1. The final expression for L of any flat figure of round wire having no re-entrant angles was found in the form

$$L = 2l\left(1 + \frac{\triangle}{100}\right)\left(\log_e \frac{2l}{r} - a_k + \mu\delta\right) .. \quad (3)$$

Particularly in the case of radiotechnical practice where $\triangle \simeq 0$ and $\mu\delta = 0$ (with

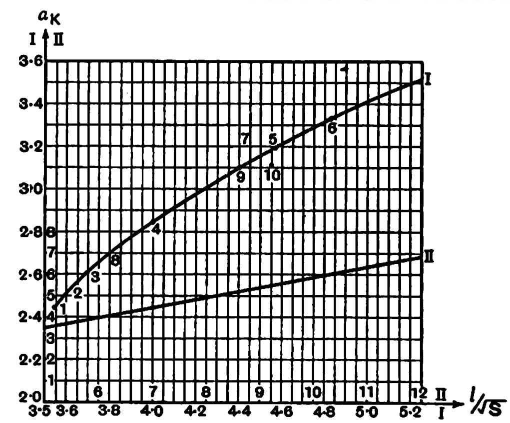


Fig. 3.

currents of radio frequency) the formula becomes

$$L = 2l\left(\log_e \frac{2l}{r} - a_k\right) \quad .. \quad .. \quad (4)$$

In using this it is convenient to use a simple nomogram (Fig. 5) for rough calculating purposes which gives an accuracy of 5 per cent. Knowing for the given figure $l/\sqrt{s}$

and l/r, noting the corresponding figures on the left and middle columns and producing the line connecting these points to cut the right-hand column, we find the value L_1, *i.e.*, the inductance in centimetres per metre of length (perimeter) of the figure. This nomogram permits solving also other cases: for instance, knowing the perimeter and radius of the wire, one can determine what area the figure must have in order that the inductance will be equal to a certain value. Also the following problem can be solved: knowing the perimeter and area of the figure, to determine the radius of the wire with which the figure would possess the necessary value of inductance.

For the sake of verifying the application of formula (1) as regards curvilinear figures an elliptical former was built up with half axes 1.5 and 3.47 m. The former was wound with copper wire ($d = 0.8$ mm.). The inductance of the ellipse was measured by means of a Siemens and Halske bridge at low frequency.

The average of seven measurements made by three investigators was $L = 30800$ ($\pm$ 1 per cent.).

The inductance of the lead-in wires was calculated to be 1,213 cm. Inductance of the ellipse calculated by means of formula (1) (a_k being taken from the curve on Fig. 3 for $l/\sqrt{s} = 4.02$) was found to be $L = 29{,}562$ cm.

Therefore the total calculated value $L = 30{,}775$ cm., which is within 0.1 per cent. of the measured value.

value of a_k from previously calculated formulæ for L of various regular figures having two variable parameters. We have three such formulæ, viz.: those for a

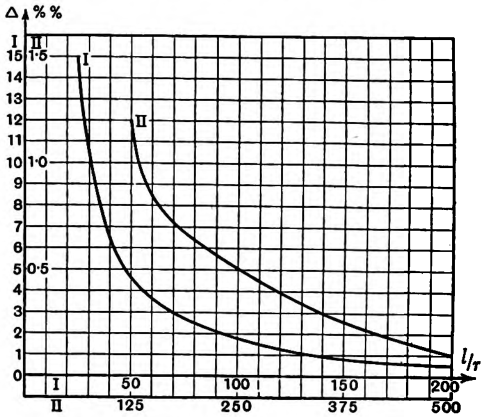


Fig. 4.

rectangle, an isosceles triangle and a rectangular triangle (see the author's papers in *Proc. I.R.E.*, Vol 15, No. 12).

The formula for a rectangle is

$$L = 4\left\{(a+b)\log_e\frac{2ab}{r} - a\log_e(a+d) - b\log_e(b+d)\right\} + 4\left[\mu\delta(a+b) - 2(d+r) - 2(a+b)\right] \quad .. \quad (5)$$

where a and b = the sides of the rectangle, d = its diagonal.

TABLE 1.

a/b	1	2/3	0.427	1/4	1/9	1/15	1/20	1/30	1/50
$l/\sqrt{s}$	4	4.08	4.37	5	6.67	8.24	9.35	11.3	14.37
a_k	2.853	2.866	3.006	3.269	3.826	4.226	4.471	4.849	5.330
$\log_e l^2/s$	2.773	2.79	2.94	3.22	3.8	4.218	4.471	4.849	5.330
$\phi = a_k - \log_e l^2/s$	0.080	0.076	0.066	0.049	0.026	0.008	0	0	0

The author extended the analysis begun by Grover (*Proc. I.R.E.*, Vol. 15, No. 12) to determine the dependence of a_k on the magnitude of $l/\sqrt{s}$ and especially (1) to determine if a depends only on $l/\sqrt{s}$ and (2) to find a mathematical formula for a_k for large values of $l/\sqrt{s}$.

For this purpose the author found the

This can be written

$$L = 2l\left[\log_e\frac{2l}{r} - a_k + \mu\delta + 4\frac{r}{l}\right] \quad .. \quad (6)$$

where

$$a_k = -\log_e\frac{ab}{l^2} + \frac{2a}{l}\log_e\frac{a+d}{l} + \frac{2b}{l}\log_e\frac{b+d}{l} - \frac{4d}{l} + 2 \quad .. \quad (7)$$

Calculating a_k for different values of a/b (*i.e.*, for different values of $l/\sqrt{s}$) we get Table 1.

We see that the dominating rôle in the formula (7) is played by the first term,

$$-\log_e \frac{ab}{l^2} = +\log_e \frac{l^2}{s}$$

The value of this term is the greater the greater $l/\sqrt{s}$ is. (See the last line in Table 1.)

Replacing a_k by the formula $\log_e \frac{l^2}{s} + \phi$ we get:

$$L = 2l\left\{\log_e \frac{2s}{rl} - \phi + \mu\delta + 4\frac{r}{l}\right\} \quad .. \quad (8)$$

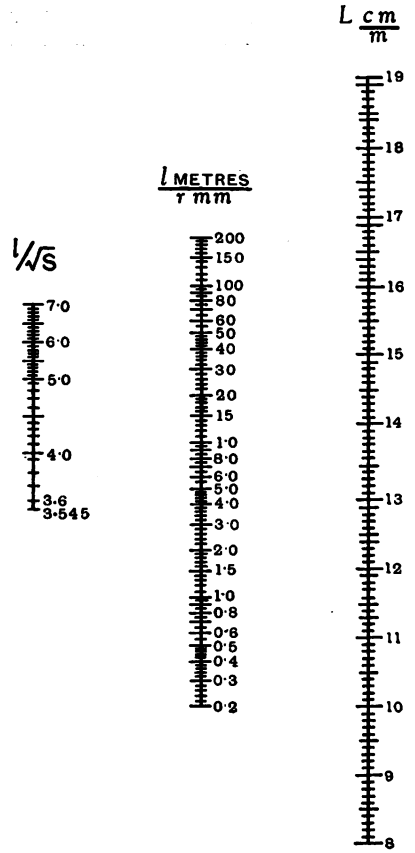


Fig. 5.

Neglecting as before for large values of $l/\sqrt{s}$, terms of the order r/l and ϕ we get:

$$L \cong 2l\left(\log_e \frac{2s}{rl} + \mu\delta\right) \quad .. \quad .. \quad (9)$$

wherefrom (as pointed out by Kliatskin) the known formula for L of long lines is found:

$$L \cong 2l\left(\log_e \frac{d}{r} + \mu\delta\right) \quad .. \quad (10)$$

in which $d =$ distance between the wires, $l =$ the length of both wires.

More exactly

$$L = (4l_1 + 4d) \log_e \frac{dl_1}{l_1 r + dr} \quad .. \quad (10a)$$

where $l_1 =$ the length of each wire.

The author thinks that also for all the other forms of closed polygons and curves having no re-entrant angles a_k is near to $\log_e l^2/s$. To prove the correctness of this analytically is unfortunately possible only for the triangle, by means of formulæ found by the author and Prof. Grover (*loc. cit.*). Only for rectangle and triangle have functions been found analytically expressing L for figures with two changeable parameters.

For a rectangular triangle (with sides a, b, and hypotenuse c), the formula is

$$L = 2\left[a \log_e \frac{2a}{r} + b \log_e \frac{2b}{r} + c \log_e \frac{2c}{r} - (a+b+c) - (a+c)\,\mathrm{arc\,sinh}\,\frac{a}{b} - (b+c)\,\mathrm{arc\,sinh}\,\frac{b}{a}\right] \quad .. \quad (11)$$

which can be written:

$$L = 2l\left[\log_e \frac{2s}{rl} + \mu\delta - \phi\right] \quad .. \quad (12)$$

where

$$\phi = -\frac{a^2}{2lc}\log_e \frac{a(c-a)}{b(c+b)} - \frac{b^2}{2lc}\log_e \frac{b(c-b)}{a(c+a)} - \frac{c}{2l}\log_e \frac{c^2}{ab} + \frac{a+\frac{c}{2}}{l}\log_e (a+c) + \frac{b+\frac{c}{2}}{l}\log_e (b+c) - \log_e l + 1 - \log_e 2 \quad .. \quad (13)$$

TABLE 2.

$l/\sqrt{s}$	4.828	5.84	7.01	8.99	10.2	12
ϕ	0.182	0.223	0.252	0.271	0.276	0.282

The calculated values of ϕ are given in Table 2.

The same calculation for a right triangle is as follows :

$$L = 2\left[2a\log_e\frac{2a}{r} + c\log_e\frac{2c}{r} - (2a+c) - 2a\,arc\sinh\frac{2a^2-c^2}{c\sqrt{4a^2-c^2}} - 2(a+c)\,arc\sinh\frac{c}{\sqrt{4a^2-c^2}}\right] \quad .. \quad (14)$$

which may be written

$$L = 2l\left(\log_e\frac{2s}{rl} - \phi + \mu\delta\right) \quad .. \quad (15)$$

where

$$\phi = 1 - \frac{2a}{l}\log_e\frac{2a}{h} - \frac{c}{l}\log_e\frac{8h}{l} \quad .. \quad (16)$$

(h = the height of the triangle). The values of ϕ are given in Table 3.

Evidently all the known expressions for L of fixed figures can be expressed in this form.

A summary is given in Table 4, where wherein n is the number of sides, R_2 = radius of the circumscribed circle, K_n = radius of the inscribed circle. We see that

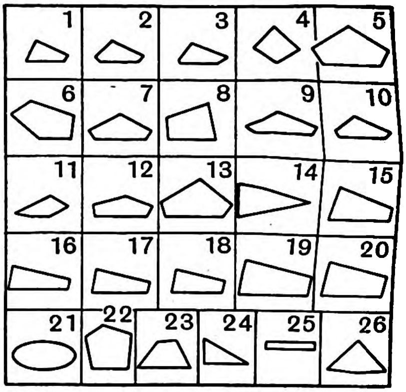


Fig. 7.

ϕ only varies between -0.08 for the circle and $+0.164$ for equilateral triangle.

Similar transformations can easily be carried out for other figures with a known

TABLE 3.

$l/\sqrt{s}$	4.559	5.67	6.94	8.01	8.95	9.8	10.59	11.3	12	**12.95**
ϕ	0.164	0.225	0.26	0.276	0.285	0.29	0.293	0.296	0.298	**0.299**

a is the side of the polygon (or the radius of the circle).

We see that for all regular polygons we

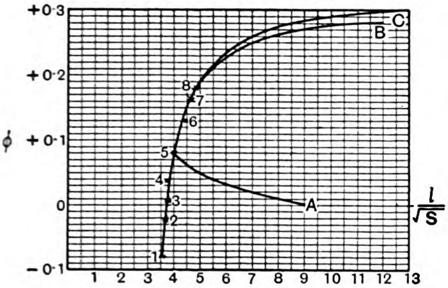


Fig. 6.

can write down a simple formula :

$$L = 2na\left\{\log_e\frac{R_2\cos\frac{\pi}{n}}{r} - \phi\right\}$$

$$= 2na\left\{\log_e\frac{K_n}{r} - \phi\right\} \quad .. \quad (17)$$

relation between l and s. As, for example, for any triangle the following formula holds

$$L = 2l\left\{\log_e\frac{R_1}{r} - \phi\right\} \quad .. \quad (18)$$

where R_1 is the radius of the inscribed circle and ϕ is found from the curve (Fig. 6).

For the rhombus with the perimeter l with an acute angle a the formula is

$$L = 2l\left\{\log_e\frac{l\sin a}{8r} - \phi\right\} \quad .. \quad (19)$$

Prof. Grover has given the following exact expression for ϕ for the rhombus :

$$\phi = (2 - \log_e 4) + \log_e\sin a - \cos\frac{a}{2} - \sin\frac{a}{2} + \cos^2\frac{a}{2}\left(arc\sinh\cot an\,a + arc\sinh\tan\frac{a}{2}\right) + \sin^2\frac{a}{2}\left(arc\sinh\cot an\frac{a}{2} - arc\sinh\cot an\,a\right) \quad .. \quad (19a)$$

On calculating ϕ for the various values of a, *i.e.*, various values of $l/\sqrt{s}$, Prof. Grover found that the law $\phi = f(l/\sqrt{s})$ is very nearly the same as for the triangle (curves B, C of Fig. 6).

The curves showing ϕ as a function of $l/\sqrt{s}$ from the Tables 1, 2, 3 and 4 are shown in Fig. 6. For the rectangle (curve A) ϕ falls to zero; for the right-angled triangle (curve B) and the isosceles triangle (curve C) ϕ increases. But the rate of increase of ϕ for $l/\sqrt{s} > 7$ to 8 is rapidly decreasing and already at $l/\sqrt{s} \cong 10$ and more ϕ for both forms is nearly constant. In general, for practical purposes for the triangular and rhomboidal forms with $l/\sqrt{s} > 12$ it is possible to assume that $\phi = 0.29$.

practical purposes to use the formula:

$$L \cong 2l \left\{\log_e \frac{2s}{rl} - 0.15\right\} \quad .. \quad (20)$$

Calculations of L by formula (12) with the data of practical measurements for the different figures shown in Fig. 7 gave the results shown in Table 5.

Comparison of the calculated and measured values shows that the errors may be expressed approximately in relation to $\frac{2s}{r}$ as shown in Table 5.

Therefore our formula should be modified as follows:

$$L = 2l\left(1 + \frac{\Delta}{100}\right)\left(\log_e \frac{2s}{rl} - \phi + \mu\delta\right) .. \quad (22)$$

TABLE 4.

No.	Form of the Figure.	$\frac{l}{\sqrt{s}}$.	Former Formula (4).	New Formula (12) where $\mu\delta = 0$.	$\log_e \frac{l^2}{s}$	$\phi = a_k - \log_e \frac{l^2}{s}$.
1	Circle	3.541	$2l\left(\log_e \frac{2l}{r} - 2.451\right)$	$4\pi a\left(\log_e \frac{a}{r} - \phi\right)$	2.53	-0.08
2	Regular octagon ...	3.641	$2l\left(\log_e \frac{2l}{r} - 2.561\right)$	$2na\left(\log_e \frac{k_n}{r} - \phi\right)$	2.58	-0.0235
3	Regular hexagon ..	3.722	$2l\left(\log_e \frac{2l}{r} - 2.636\right)$		2.63	$+0.0065$
4	Regular pentagon ..	3.812	$2l\left(\log_e \frac{2l}{r} - 2.712\right)$		2.68	$+0.0355$
5	Square............	4.000	$2l\left(\log_e \frac{2l}{r} - 2.853\right)$	$8a\left(\log_e \frac{a}{2r} - \phi\right)$	2.77	$+0.08$
6	As per Fig. 7	4.395	$2l\left(\log_e \frac{2l}{r} - 3.091\right)$	$2l\left(\log_e \frac{0.1036l}{r} - \phi\right)$	2.96	$+0.13$
7	Equilateral triangle	4.559	$2l\left(\log_e \frac{2l}{r} - 3.197\right)$	$6a\left(\log_e \frac{a}{2\sqrt{3}r} - \phi\right)$	3.03	$+0.164$
8	Isosceles right triangle (equal sides).	4.828	$2l\left(\log_e \frac{2l}{r} - 3.331\right)$	$(2 + \sqrt{2})\left[\log_e \frac{a}{(2 + \sqrt{2})r} - \phi\right]$	3.15	$+0.182$

In practice the value of ϕ can be taken from Fig. 6. If the figure has $l/\sqrt{s} > 4$ and has a contour differing considerably from the triangles (curves B and C) and the rectangle (curve A) the author thinks it possible for

This discrepancy (1) lies near the limits of the accuracy of measurement, (2) is natural because in almost all cases (except No. 21) the inductance of lead-in wires (to the measurement bridge) was neglected.

In conclusion I would like to express my heartiest thanks to Prof. Grover of Schenectady (U.S.A.) who in the course of two years showed the most lively interest in my work, gave me a great amount of most valuable advice, and verified the results found by me. I also express my thanks to Prof. M. V. Schuleikin and B. A. Vvedensky, both of Moscow, for their interest and advice in carrying out the experiment. For the most part the experiments were carried out at the Radio Department of the State Electrical Research Institute; I am obliged especially to my pupils, El. Eng. M. E. Starik and Eng. N. K. Swijtoff, who besides their work in the measurements afforded me very real help by making some of the calculations.

TABLE 5.

	Closed Aerials and Circuits.		Perimeter l.	Area s.	$l/\sqrt{s}$.	Radius of Wire.	L Measured $\times 10^3$.	L Calculated [formula 12] $\times 10^3$.	ΔL per cent.
1	The closed aerials of Lübertzy's radio receiving station near Moscow (Types 1920–1924)	Warsaw	285	3,705	4.68	0.2	552	544	−1.44
2		Nauen	310	4,343	4.68	0.2	606	597	−1.51
3		San-Paolo	315	4,315	4.794	0.2	609	604	−0.80
4		Paris I	160	1,593	4.00	0.2	308	300	−2.49
5		South	275	4,525	4.08	0.2	565	542	−3.99
6		Tashkend I	304	4,816	4.38	0.2	598	594	−0.61
7		S.E.	335	5,736	4.42	0.2	685	660	−3.68
8		Carnarvon I	220	2,794	4.17	0.2	445	421	−5.34
9		Carnarvon II	375	5,868	4.89	0.2	753	729	−3.24
10		Paris II	370	5,038	5.2	0.2	740	707	−4.31
11		Tashkend II	350	5,005	4.95	0.2	695	677	−2.62
12		America	385	6,234	4.87	0.2	785	754	−3.95
13		West	330	4,352	5.00	0.2	666	629	−5.49
14	The isosceles triangle		45.2	85	4.9	0.1	81	75	−7.42
15	The irregular quadrilateral		44.9	161	4.46	0.1	76.5	76	−1.44
16	The irregular quadrilateral		61.4	158	4.88	0.1	104	106	+1.67
17	The irregular quadrilateral		57.85	152	4.69	0.1	100	100	−0.81
18	The irregular quadrilateral		54.3	141	4.57	0.1	95	94	−1.33
19	The irregular quadrilateral		50.7	135	4.365	0.1	89	88	−1.01
20	The irregular quadrilateral		47.2	122	4.275	0.1	83	82	−1.37
21	The ellipse		see page 5		4.02	0.04	30.8	30.8	−0.1
22	The irregular pentagon		52.12	185	3.81	0.1	98	95	−3.28
23	The irregular quadrilateral		45.94	115	4.28	0.1	75	79	+4.82
24	The right-angled triangle		15.92	9.86	5.07	0.04	25.5	26	+1.07
25	The rectangle		70	150	5.71	0.1	121.5	120	−1.17
26	The Marconi d.f. aerial		97.5	330	5.37	0.1	164	173	−5.39

ΔL per cent. (mean value for 26 examples), − 2.13 per cent.

$\frac{2s}{rl}$ — of the order .... 10^6 $\Delta L = 1.1$ per cent. $\frac{2s}{rl}$ — of the order .... 10^3 $\Delta L = 2.2$ per cent.

$\frac{2s}{rl}$ — of the order .... 10^2 $\Delta L = 3.3$ per cent.

The Measurement of the Voltage Amplification Factor of Tetrodes.

By W. Jackson, M.Sc.

THE main advantage possessed by the screened grid valve or tetrode over the triode is its ability to provide high values of the mutual conductance $\frac{\mu_0}{R_p}$, where μ_0 is the voltage amplification factor and R_p the alternating current plate-filament resistance, with high values of μ_0 at comparatively low plate voltages. The quantities μ_0 and R_p may be derived from the valve characteristics, obtained by a continuous variation of one of the battery voltages with the remainder constant, but an investigation of their variation with plate, screen and control grid voltage is by this method a long and tedious process. The use of a slightly modified form of Miller's alternating current bridge has enabled the values of μ_0 and R_p to be measured directly, simultaneously with the recording of the valve characteristic; so that their variation over the characteristic could be analysed at once. This is of importance in view of the variety of conditions of battery voltages under which these valves may be used in practice and especially when operated under conditions of gradually falling battery pressure, as occurs with dry high-tension batteries.

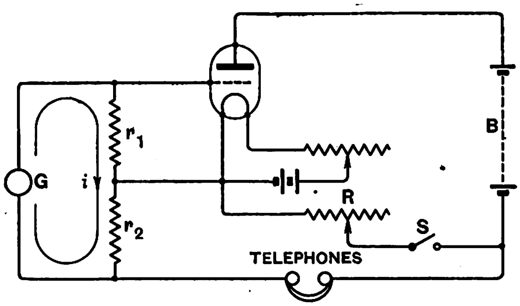


Fig. 1.—*Bridge for triode measurements.*

A diagrammatic sketch of the bridge arrangement for triode measurements is shown in Fig. 1, in which r_1, r_2 and R are variable non-inductive resistances, G a coupling coil to a valve generator of audio frequency currents and Ph: a pair of headphones of low resistance compared with the tube resistance.

With the switch S open, the ratio of r_2

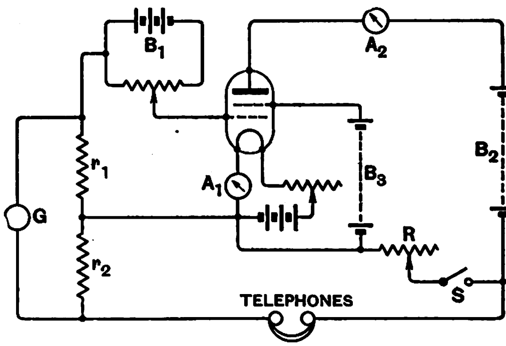


Fig. 2.—*The modified arrangement for use with four-electrode valve.*

to r_1 is varied until no sound is heard in the phones, when

$$u_0 i r_1 = i r_2$$

or

$$u_0 = \frac{r_2}{r_1} \quad \ldots \quad \ldots \quad (1)$$

With the switch S closed, the ratio $\frac{r_1}{r_2}$ is fixed and R varied until no signal is audible in the headphones, then, with this adjustment

$$\frac{\mu_0 i r_1}{R + R_p} \cdot R = i r_2.*$$

$$R_p = R\left(\mu_0 \frac{r_1}{r_2} - 1\right) \quad \ldots \quad (2)$$

The use of these two balance conditions enables the values of the voltage amplification factor and of the plate filament resistance to be measured for any battery voltages; the latter determining the steady plate current, from which the valve characteristic may be plotted, on which is superposed an alternating component of plate current caused by the variation of grid potential due to the audio input signal.

It is important in making the measurements to work with as small an alternating

* Appendix.

input voltage as possible since the plate-filament resistance must vary throughout the cycle of grid potential and thus tend to render the production of complete silence at the balance point in the measurement of R_p impossible. For the same reason, it is advisable to keep r_1 and r_2 small throughout the measurements.

The modified circuit arrangement for use with a four-electrode valve is given in Fig. 2, a milliammeter is shown included in the plate circuit to enable the valve characteristic to be plotted, along with the measured values of μ_0 and R_p, against the variable battery voltage.

The curves of Fig. 3 show the variation with anode voltage of the plate current, voltage amplification factor μ_0, alternating current plate filament resistance R_p, and mutual conductance $\frac{\mu_0}{R_p}$, for constant filament current, control and screen grid voltages for an S625 tetrode. They serve to show that the flat portions of the valve characteristic at A, B and C are those of high voltage amplification factor while on the steep parts between A and B and between C and O, μ_0 becomes very small. It is interesting to note that a change in anode pressure from 100 to 80 volts leads to a change in μ_0 from 110 to 2.5, for a constant screen voltage of 80. While the voltage amplification obtainable at B is high the low value of $\frac{\mu_0}{R_p}$ renders this portion of the curve of small utility compared with the flat portion of the curve at A. Over the portion BC of the characteristic the alternating current plate-filament resistance is negative and both R_p and μ_0 were indeterminate over this range.

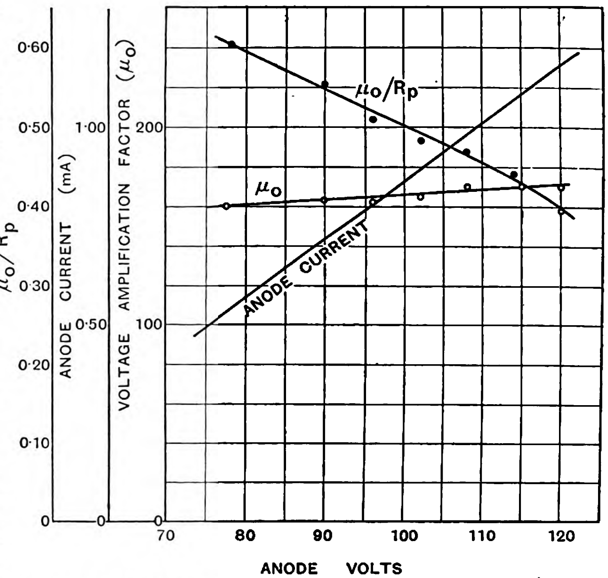


Fig. 4.—*Filament current 0.25 amp.; control grid at zero potential.*

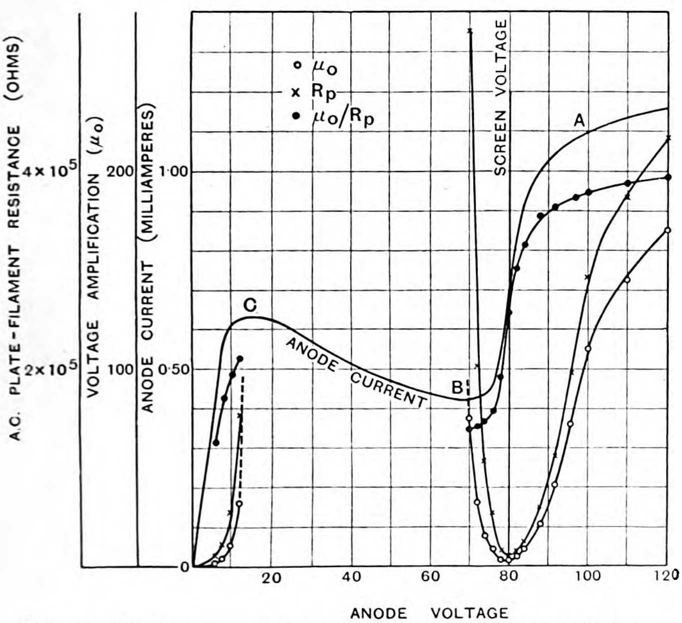


Fig. 3.—*Filament current 0.25 amp.; control grid at zero potential.*

It would appear that a variation in anode voltage may be attended by a serious drop in the voltage amplification obtainable from a stage of high frequency amplification employing a four-electrode valve. Since, however, the anode and screen voltages are in general taken from a common supply, the effect of a drop in battery pressure is not so serious, as will be seen from a consideration of the curves of Fig. 4. These curves

were obtained with varying anode pressure but with a constant ratio of anode to screen voltage such as might occur in the case of a set operated from dry high-tension batteries. The voltage amplification factor shows a slight decrease with decreasing anode and screen voltages, but at the same time the mutual conductance increases, indicating a probable increase in stage amplification together with a decrease in high-tension supply current required.

Essentially similar results to those recorded in Fig. 3 were obtained in a series of measurements on the P.M.12 four-electrode valve. A change in anode pressure from 120 to 80 volts with normal filament, control grid and screen grid voltages produced a change in μ_0 from 210 to 2.

Fig. 5 shows a series of curves obtained with constant plate and control grid voltages but with varying screen voltage. Both μ_0 and R_p increase with decreasing screen voltage producing a small decrease in the mutual conductance $\frac{\mu_0}{R_p}$.

The effect of variation of control grid voltage with normal conditions of plate and

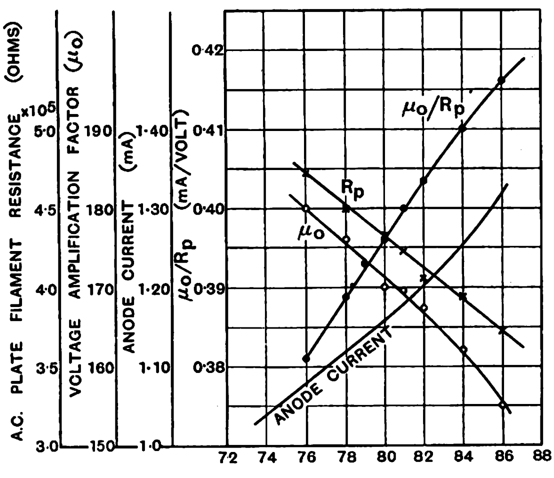


Fig. 5.—*Anode volts 120, filament current 0.25 amp.; control grid at zero potential.*

screen voltages is shown in Fig. 6. The anode current-grid voltage characteristic is straight for a grid swing of 1.5 volt, while little variation in μ_0 was noticeable with grid voltage.

The results indicate that tetrodes when operated from dry batteries providing a decreasing high-tension voltage with time operate satisfactorily so long as the anode

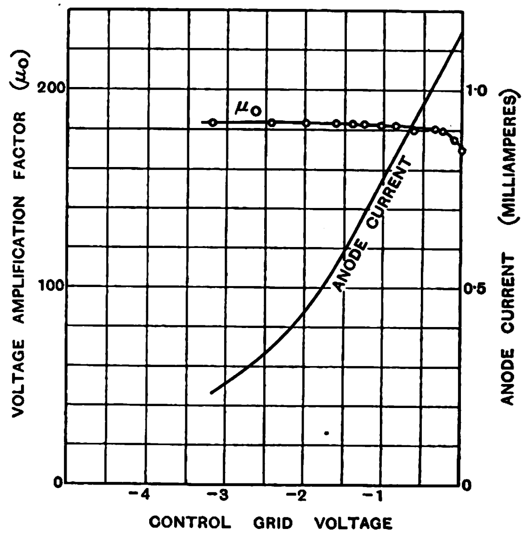


Fig. 6.—*Effect of variation of control grid voltage.*

and screen voltages vary from their normal values simultaneously and in doing so ensure continuous operation on the flat portion *A* (Fig. 1) of the anode current-anode volts characteristic.

Appendix.

An alternating voltage ir_1 impressed between grid and filament will produce an equivalent alternating voltage in the plate circuit equal to $\mu_0 ir_1$. This voltage will cause an alternating current $\frac{\mu_0 ir_1}{R + R_p}$ to flow in the plate circuit, superposed on the steady current produced by the steady plate and grid voltages. The voltage drop across R due to this alternating current equals $\frac{\mu_0 ir_1}{R + R_p} . R$, which, for no sound in the phones, must be balanced round the local circuit consisting of r_2, R and the phones by the voltage ir_2 across r_2, from which

$$\frac{\mu_0 ir_1}{R + R_p} . R = ir_2.$$

An Investigation of Short Waves

(Paper by Mr. T. Eckersley, B.A., B.Sc., read before the Wireless Section, Institution of Electrical Engineers, on 10th April, 1929.)

ABSTRACT.

THIS is a very extensive paper on the subject of Short Waves. The discussion is grouped under the main heads: (1) Echoes and Scattering, (2) Direction-Finding Results, (3) Fading (including the effect of Magnetic Storms), (4) Theory.

(1) Echoes and Scattering.

The author suggests that perhaps the main interest in short-wave transmission lies in echo and scattering effects. He classes them together because in the long run the two effects merge into one. Signal distortion, due to echoes and scattering, imposes a severe limitation on high-speed working and on facsimile transmissions. The time lag of echoes and multiple signals may be anything from 0.001 sec. (observed in facsimile transmissions) up to the 25 secs. observed by Stormer and Van der Pol, but it is the short echoes up to 0.1 second or so which are associated with scattering.

In a previous paper,* the author suggested the existence of considerable scattering of short waves, and the two years' intensive study which has intervened confirms his ideas on this subject.

A two-aerial system is described, in which signals from any station not too nearly in line with the aerials can be balanced, provided the energy is travelling along any ray or set of rays in the vertical plane. From the results of observations with this it is assumed that close to the transmitting station the direct ray, with its definite direction of existence of a main ray together with a scattered residue which remains when the main ray has faded out. Scattering in this sense merely implies the existence of energy travelling to the receiver along more than one path in the horizontal plane, and is, in its ultimate analysis, an irregular reflection.

The aerial system referred to led to the development of an Adcock direction finder, one limb of which is shown in Fig. 2.† The arrangement is stated by the author to be better as a means of investigating transmission than as a direction finder.

The results obtained were very diverse and varied. One very peculiar result has occurred on the bearings of British beam stations working to great distances. In the majority of cases, a more or less defined bearing is found which is close to the bearing of the distant station to which the British beam transmission is working. As an example, the Grimsby beam, working to Australia, gave bearings close to the bearings for Australia, and Bodmin, working to South Africa, gave bearings close to those of South Africa. The explanation offered by the author is that the direct rays from the beams are so weak as to be negligible and the rays received at Broomfield (near Chelmsford) are those scattered back from the regions where the main transmitted beam penetrates into the scattering regions of the Heaviside layer—like the case of a searchlight (itself invisible) playing on a reflecting cloud. From an analysis given, it is concluded that quite an appreciable amount of

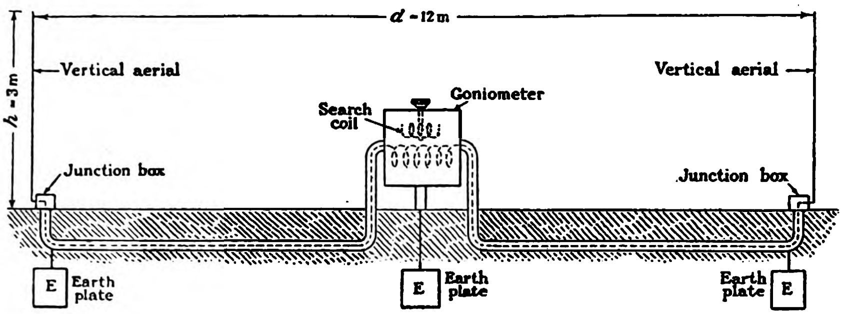


Fig. 2.

travel, is predominant. The direct ray is attenuated very quickly, and at distances of a few miles (depending on the wavelength, nature of the transmitting aerial, etc.) this direct ray is swamped by radiation scattered from the Heaviside layer. At great distances the evidence points to the energy is scattered back from distances of about 2,000 km.

The author discusses mutilation of signals at some length and concludes that this may arise from the following causes:—

(1) *Long Echo*, due to signals arriving by the two

* Jour. I.E.E., 1927, Vol. 65, p. 600. Abstract in *E.W. & W.E.*, 1927, Vol. 4, p. 213.

† The Author's original figure numbers are adhered to throughout this abstract.

different great-circle paths round the world, or by one traversing an extra complete circumference of the world. These effects are easily recognisable, but taking due account of them there are, no doubt, other causes of signal mutilation.

(2) *Quick Echo.*—There are cases of quick echo with a lag of the order of 0.01 sec., which are probably due to long-distance scattering, such as mentioned above in connection with the beam stations.

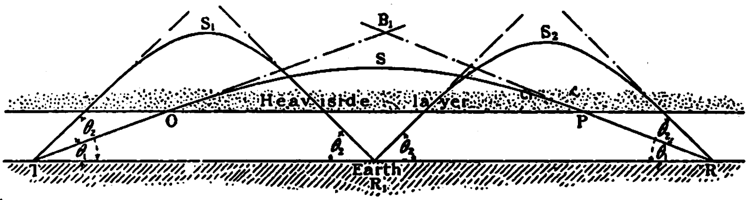


Fig. 11.

(3) *Blurring*, due to multiple scattering. This probably occurs mostly on local signals.

(4) *Double signals or multiple signals*, due to double or multiple paths. These produce double or multiple signals with a time interval between signals of the order of 0.01 sec. They have been brought to light by picture transmission results, but are not likely to mutilate Morse signals.

The last three effects are likely to contribute to mutilation in different proportions according to the actual conditions of transmission.

There may also be mutilation due to dispersion, as any signal changes shape when travelling through a dispersive medium such as the Heaviside layer. Reasons are given for supposing that this effect is negligible on the short-wave band, although there is evidence of dispersion effects on very long waves, *e.g.*, musical Xs.

Scattering also introduces an additional attenuation, since the fact that energy is scattered out of the main path of a beam must reduce the useful energy received, broaden the beam, and produce an effective attenuation over and above that normally produced by the resistivity of the conducting layer.

The author states that scattering is observed on all wavelengths from 50 m. downwards, but does not appear to exist in the broadcast band. Recent experiments have also shown that there is very little scattering on the 75–100 m. band.

In considering the mechanism of scattering, the author postulates a layer in the form of a complicated structure of ionic clouds. The average distance between clouds must be large compared with the wavelengths under consideration (*i.e.*, below 50 m.), but small compared with 300 m. Consideration of the ionic density suggests that the scattering layer is confined to regions below 115 km. and does not vary much from day to day.

(2) Direction-Finding Results.

Bearings can be roughly divided into three classes:—

(*a*) Correct or approximately correct.

(*b*) Definitely wrong, but having some distinct characteristic, *e.g.*, local beam station bearings (already mentioned) or bearings perpendicular to the true direction.

(*c*) Nil bearings, when little or no sign of direction is given by the gomometer.

An extensive table of results is given of nine months' regular interception in 1928.

In the table, distant stations, normally outside the skip distance, show as a rule 100 per cent. true bearings, but there are occasional cases of right-angled bearings. These occur almost invariably when signals are weak and transmission conditions along the direct route are poor.

Observations on stations within the skip distance show almost complete absence of true bearings. Longer wave stations in general show some true bearings, but the percentage is small. True bearings generally imply that for some reason the station was, at the time, beyond the skip distance. It is generalised that within the skip distance scattering predominates, and that outside it the main ray predominates.

Right-Angled Bearings.—On occasions when the main ray from a station is obliterated, due to adverse conditions on the true great-circle route, signals may pass to one or the other side of the receiving station. The energy is then scattered from the nearest point of the energy flow to the receiver. An illustration of this effect is shown in Fig. 13. In the case of one station 22 per cent. of the bearings gave a mean direction 91.6 deg. from true bearing.

Sunset Effects.—There is some evidence of considerable variation of bearings during sunset periods. The effect has been very noticeable on Vienna and Cairo, and at times on Lisbon, Rio and other South American stations. An example is given in Fig. 14. The error is in general such as

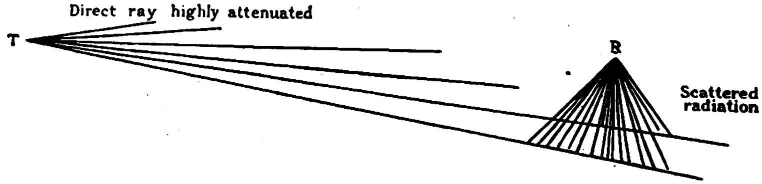


Fig. 13.

might be produced by horizontal refraction in the Heaviside layer.

Very short skip distance effects.—In some recent experiments reflection at practically normal incidence from the Heaviside layer has been observed on waves down to 30 m. At 11.27 km. distance, all waves from 60 to 30 m. showed marked vertical reflection, which appeared to be less on the longer

waves than on the shorter. These results are interesting in connection with the very long (Stormer) echoes.

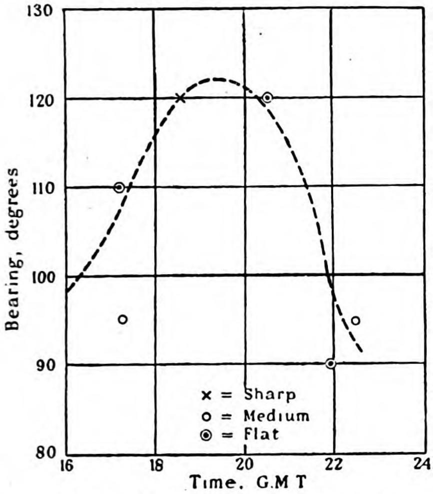


Fig. 14.—*Vienna* (*OHK*, 39.95 *m.*).

(3) Fading.

The multiple signals, of which the total received signal is composed, will not all arrive in phase. Interference of the components will produce fading as the relative phases change. The character of the fading will depend on the number of signals arriving at any moment and the rapidity with which relative phases change. There is also another type of fading due to change on the plane of polarisation. In its ultimate analysis this is also a case of interference, for it is the interference between two circularly polarised rays, travelling with slightly different velocities, that produces the change in the plane of polarisation.

In connection with interference fading, illustrations are given implying two, three or four separate paths. The simplest explanation, consistent with the facts, is of two rays, one making a single jump and one making a double jump, as in Fig. 11. Multiple signals in this case imply multiple ricochets between the earth and the Heaviside layer.

This type of interference can be greatly reduced by adding the effects of two slightly different frequencies, for if the path difference d remains constant it is possible to choose two wavelengths λ_1 and λ_2 so that the fading of the two is inverse. Thus, if N = number of $\frac{1}{2}$ wavelengths of λ_1 in d, *i.e.*, $N\lambda_1 = d$, then for phase equality $N = 2n$, where n is an integer. For interference

$$(2n + 1)\lambda_2 = d$$

or

$$\frac{\delta\lambda}{\lambda} = \frac{df}{f} = \frac{1}{4n},$$

where $\delta\lambda = \lambda_1 - \lambda_2$, in the particular case where $d = 300$ km., $\lambda = 20$ m. and $\delta f = 500$ cycles.

If a station sends a marking and a spacing wave of this order of frequency, fading on the two waves is quite different. The advantage of this method can be obtained by modulating the emitted waves with a 500-cycle note and heterodyning the received note. The rectified current will then consist of f_1, $(f_1 + 500)$ and $(f_1 - 500)$, where f_1 is the beat frequency of the heterodyne and carrier wave. The mean square value of the total rectified current should then remain constant, unless complicated by multi-ray and polarisation fading. Recent tests seem to indicate that there is a big gain in using modulated waves instead of pure c.w., with a much higher speed of working.

The fading on two aerials spaced many wavelengths apart is also found to be very different, and an experiment on this subject is being carried out jointly by the Marconi Co. and the B.B.C. Statistical calculations suggest that the variability is reduced to about half for two rays. If limiting can be resorted to, it is only the occasions when signals are reduced to below a certain limiting value that are likely to be troublesome. If the limiting value is about $\frac{1}{3}$ R.M.S. strength, a gain of 20 to 1 may be possible. Fig. 20 shows records

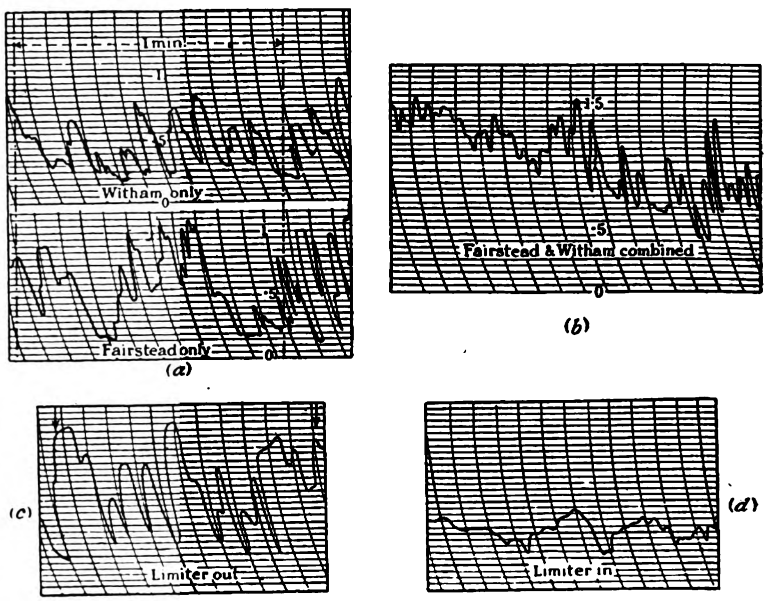


Fig. 20.

of combined signals compared with signals taken from each aerial separately.

Experiments are also described on the combination of signals from a horizontal and from a vertical aerial. Results with the arrangement described showed that there were considerable differences in the fading, but it is difficult to give any numerical estimate of the gain likely to accrue from the addition of the rectified currents.

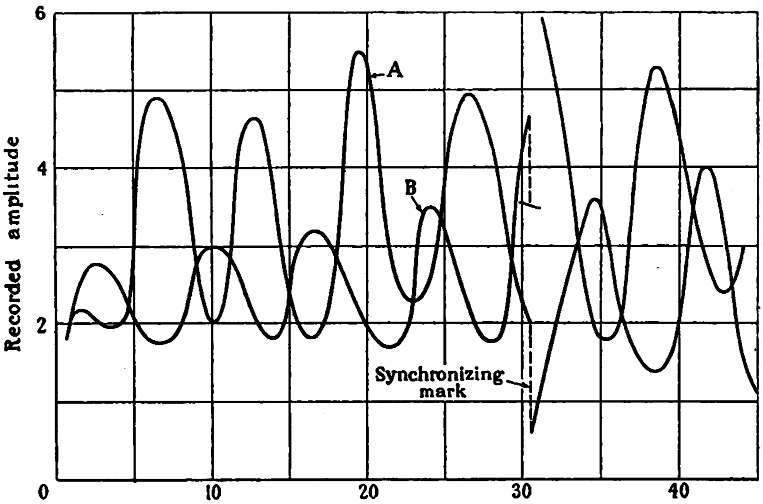


Fig. 24.—*Signals from PQW (Lisbon, beam, 15.6 m.) sending high-speed dots.*

(and incidentally less attenuated) of the two rays, circularly polarised by the earth's field, alone is received; at slightly greater distances both rays combine and produce marked inverse or "polarisation" fading, as it might be called; at great distances the horizontal ray diminishes in importance and the fading is mainly of the "interference" type.

Magnetic Storms.—The systematic observation of short-wave transmissions has provided an opportunity of testing the effect of magnetic storms. The general effect is to produce a "fade-out" on short-wave transmissions and to reduce attenuation on long-wave transmissions.

It is assumed that in a magnetic storm electrified particles are shot out from disturbed areas of the sun and in certain circumstances enter the upper layers of the atmosphere in regions surrounding the magnetic poles, producing mass movements of the electrons and ionised molecules. This sets up currents which disturb the earth's magnetic field.

Long-distance short-wave attenuation takes place in the lower regions of the Heaviside layer and is proportional to N/τ, where N

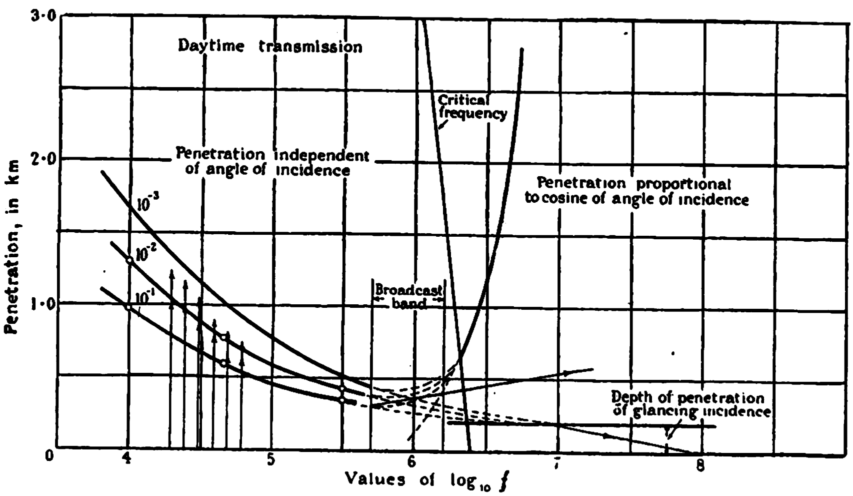


Fig. 29.

An example of simultaneous record from a horizontal and vertical aerial is given in Fig. 24.

In connection with fading effects, it is concluded that in the skip distance no direct ray is received; at the edge of the skip distance the more bent

is electronic density and τ the mean time between collisions. An increase of N due to a magnetic storm will drop the layer into a region of higher pressure where τ is less. Both effects will increase N/τ and increase short-

wave attenuation. The effect on long waves will depend on whether the change in N or in τ is the more potent factor. If the change in N is the predominating factor, magnetic disturbance will increase short-wave and decrease long-wave attenuation, as is usual.

As magnetic storm disturbances are more violent at the polar regions, signals passing these regions are likely to be more subject to fades from this cause. This is the case in practice, Canadian and American stations being more subject to magnetic-storm fades than Indian and South American stations.

The author also mentions a considerable increase of "whistlers" during magnetic storms. These are very long-wave atmospherics which can be heard giving a whistling sound, with telephones directly in the aerial, or with the aerial joined to an audio-frequency amplifier alone, without high-frequency tuning or rectification.

(4) Theory.

The concluding section of the paper discusses theory, more particularly of the Heaviside layer and its rôle in transmission. The conception of the layer as a complex structure of scattering clouds necessitates revision of the usually accepted ray theory. If the scattering in the lower levels of the layer is particularly intense, the emergent ray may be very highly diffused and the emergent energy may entirely lose its ray formation.

Arising from the author's calculations, Fig. 29 shows the penetration into the layer on the various frequencies over the whole of the working wireless waveband, *i.e.*, $f = 10^8$ to $f = 10^4$. The wavelength spectrum may conveniently be divided into three regions, those for which $f >> 1/\tau$, those for which $f << 1/\tau$, and finally the intermediate range which corresponds very fairly to the broadcast band. For the first (short wave) group, the depth of penetration depends on f and the angle of incidence. For long waves the depth of penetration is independent of the angle of incidence, and there is no sharp line of demarcation.

The author also calculates the joint effect of frequency and angle of incidence, and gives his results in Fig. 30, which is a perspective view of a solid diagram representing the total ray attenuation as a function of each of these factors. In the absence of definite knowledge of the density at any given height, only relative values are given, but it is seen that the example exhibits also the observed characteristics of skip effects. For any given wavelength, for instance, attenuation increases up to a maximum at some intermediate angle and then decreases up to normal incidence. At normal incidence the attenuation increases with increasing wavelength and at small incidence decreases with increasing wavelength. The diagram is, of course, not correct at glancing incidence.

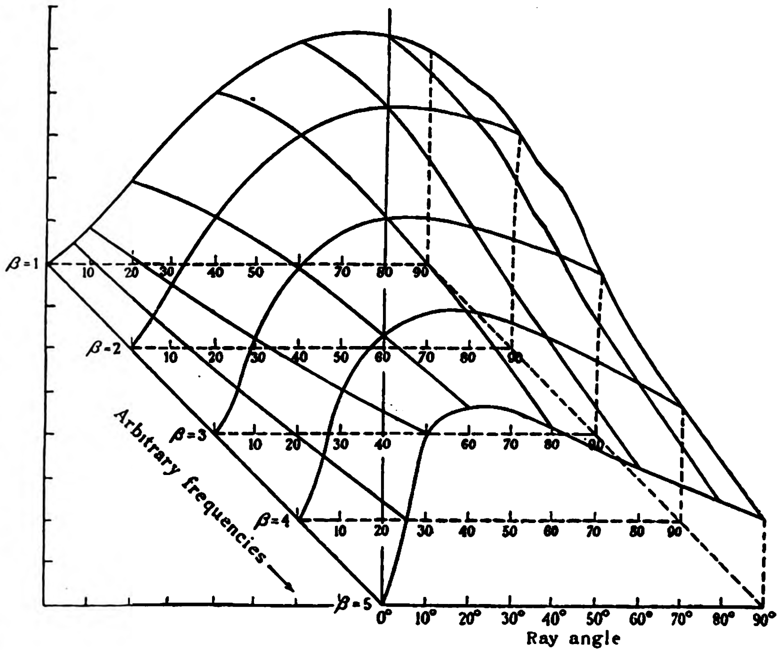


Fig. 30.—*Attenuation diagram in skip distance.*

The work described by the author has been carried out in the Research Dept. of Marconi's Wireless Telegraph Co., at Chelmsford.

DISCUSSION.

The unusual length of the paper curtailed the time available for discussion, which was therefore much shorter than usual.

In opening the discussion Dr. R. L. Smith-Rose referred to the enormous work which the paper represented. The fact that details of experimental methods were largely put in the background was made up for by the excellent analysis of the results obtained.

With reference to the Adcock aerial scheme (Fig. 2) he criticised the arrangement of buried cable shown. Such cable was not screened from horizontal electric forces. He also discussed the effect of the current in the horizontal portion (when signals were actually being received) upon the vertical aerial. The author's results upset previous ideas which Mr. Barfield and he had gathered from the Adcock system on broadcasting waves, viz.: that it was free from night error. He suggested that the dispersion effects discussed by the author might be used to explain Störmer (long-period) echoes within the atmosphere. One

of the alternative theories of these echoes, due to Prof. Appleton and Dr. van der Pol, already led to such an idea. The evidence of Fig. 24 was very interesting and afforded confirmation of the fact that fading could be due to change of polarisation.

MR. J. E. TAYLOR said he was much impressed by the beam D.F. results. These left no doubt about scattering from the fact that waves might travel round the globe several times, one would expect antipodean regions of concentration of waves. Had this been found? He would be glad of more information on the difference between short and long waves for the same power. Whistlers were very clear on telephone lines, and he had previously connected them with the entry into the atmosphere of meteoric matter.

MR. R. A. WATSON WATT suggested that the author's work could have been facilitated by the use of the cathode-ray system of direction finding, and thought that it would be better to get results by converting the incoming signals to something that could be watched. The Adcock D.F. aerial and cathode ray indication would be excellent for studying scattering. Friis had shown that, in frequency changing from a common oscillator, relative phase of the high frequency was conserved in the audio frequency. With reference to magnetic storms he illustrated a record from long-wave atmospherics-recording apparatus, showing a marked increase of atmospherics intensity at a time (10th October, 1928) when the author had noted short-wave fade-out, although no magnetic storm was reported. On the subject of "whistlers" he suggested that the author already had an excellent method of observation of these in the facsimile transmission work mentioned in the paper.

MR. T. L. ECKERSLEY briefly replied to some of the points in the discussion, and on the motion of the chairman (Commander J. A. Slee, C.B.E.) the author was cordially thanked for his paper.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Effect of Anode-Grid Capacity in Anode-Bend Rectifiers.

To the Editor, E.W. & W.E.

SIR,—In the last paragraph of my article on the above subject in your March issue, the statement is made that with anode-bend detectors only a comparatively small increase of resistance is caused by feed-back through the anode-grid capacity. I regret I did not make it clear that in saying this I was referring only to anode-bend detectors working under the conditions of low amplification factor, of the order 0.1 to 0.2, contemplated by Mr. Medlam in his article on the same subject.* With normal values of amplification factor the increase of resistance may be very considerable, as is easily seen by inserting numerical values in formula (36).

E. A. BIEDERMANN.

Brighton.
March 11, 1929.

Frequency Modulation.

To the Editor, E.W. & W.E.

SIR,—In the March number of *E.W. & W.E.*, is described a recent patent: Signalling by frequency modulation; a system obviously based on the same principle is described in the November number last year.

In the first-mentioned description, it is said that "the width of the side-bands is stated to be reduced to a few hundred cycles only." This result seemed to me to be of such great importance in these days of an overcrowded ether that I took a special interest in the matter. I tried to solve the problem mathematically, but came to a result quite different from that stated in the description. This may, of course, be due to an error in my conception of the system, but if so I would be glad to have it pointed out.

The modulated high-frequency current may be

$$i = A \sin (\omega t + k \sin mt) \qquad .. \quad .. \quad (1)$$

written where A is the constant amplitude, ω the (cyclic) frequency of the carrier, m the modulating frequency, and k a modulation constant, the latter determining to what extent the carrier-frequency is varied.

The "instantaneous frequency" of the modulated current as written in (1) may be determined by differentiating the expression in the parentheses with regard to time:

$$n = \frac{d(\omega t + k \sin mt)}{dt} = \omega + km \cos mt \quad .. \ (2)$$

The "instantaneous frequency" thus oscillates between the limits $\omega + km$ and $\omega - km$.

For further investigation the equation (1) is written:

$$i = A \sin \omega t \cos(k \sin mt) + A \cos \omega t \sin(k \sin mt) \qquad .. \quad .. \quad (3)$$

Now the terms $\cos(k \sin mt)$ and $\sin(k \sin mt)$ are periodic with the period $\frac{2\pi}{m}$; hence they may be expanded in fourier-series; it is easily seen that these series can be written:

$$\cos(k \sin mt) = a_0 + a_1 \cos mt + a_2 \cos 2mT + \ldots$$
$$\sin(k \sin mt) = \qquad b_1 \sin mt + b_2 \sin 2mt + \ldots$$

* "Effect of Anode-Grid Capacity in Detectors and L. F Amplifiers," by W. B. Medlam, B.Sc., A.M.I.E.E.. *E.W. & W.E.*, Oct., 1928.

Hence the expression (3) for i can be written:

$$= a_0A \sin \omega t + a_1A \sin \omega t \cos mt + a_2A \sin \omega t \cos 2mt + \ldots$$
$$b_1A \cos \omega t \sin mt + b_2A \cos \omega t \sin 2mt + \ldots$$

$$= a_0A \sin \omega t + \frac{A}{2}(a_1 + b_1) \sin (\omega + m)t + \frac{A}{2}(a_1 - b_1) \sin (\omega - m)t + \frac{A}{2}(a_2 + b_2) \sin (\omega + 2m)t + \frac{A}{2}(a_2 - b_2) \sin (\omega - 2m)t + \ldots$$

It is seen that the current contains not only the carrier and the usual side-bands $\omega + m$ and $\omega - m$, but also side-bands of the harmonics of the modulating frequency; and it does not at all—as could perhaps be expected—contain the side-bands $\omega + km$ and $\omega - km$.

When k is small compared with unity $\left(e.g., k = \frac{1}{10}\right)$, in the expression (3) $\cos (k \sin mt)$ may be replaced by 1 and $\sin(k \sin mt)$ by $k \sin mt$. With this approximation we get:

$$i = A \sin \omega t + Ak \cos \omega t \sin mt$$
$$= A \sin \omega t + \tfrac{1}{2}Ak \sin (\omega + m)t - \tfrac{1}{2}Ak \sin (\omega - m)t.$$

This is, in fact, the expression for an ordinary amplitude modulated wave. For small values of k the method is thus identical with the usual method of modulation (though not with regard to the phase of the sidebands); for greater values of k much broader sidebands are introduced.

N. E. HOLMBLAD.

The Transmitting Station actually sends out Waves of One Definite Frequency but of Varying Amplitude.

To the Editor, E.W. & W.E.

SIR,—May I enter the correspondence on the above subject.

The practical problem is to deduce in one's head the main characteristics of the output from a system, the input to which is a modulated carrier oscillation.

We have $\theta = \phi(I)$, meaning that the output θ is a function of, or the result of an operation ϕ on the input I. We may consider I as the sum of, say, three components X, Y and Z (carrier and two sidebands), but if we do this we must guard against saying that $\theta = \phi(X) + \phi(Y) + \phi(Z)$ in all cases. This is the mistake made at first by Mr. Aughtie, leading to his false conclusion. Messrs. A. B. Howe and Biedermann consider the case $\phi(I) \equiv AI + BI^2$, where A and B are constants. They point out that the output is $A(X + Y + Z) + B\ (X + Y + Z)^2$ and not $(AX + BX^2) + (AY + BY^2) + (AZ + BZ^2)$. In some cases, however, we do have $\theta = \phi(X) + \phi(Y) + \phi(Z)$, one of the most common being the case of the oscillatory circuit. The problem is to find θ from an equation of the form $L\frac{d^2\theta}{dt^2} + R\frac{d\theta}{dt} + C\theta = I$. The components X, Y and Z of I each give a particular integral in the solution; let these be $\phi_1(X)$, $\phi_2(Y)$, $\phi_3(Z)$, then the complete solution is $\theta = \phi_1(X) + \phi_2(Y) + \phi_3(Z) +$ (complementary function). The reason why in this case it is simpler to think of I as carrier and sidebands, is that $\phi(\ )$ is itself a function of I and extremely complicated, whereas $\phi_1(\ )$, $\phi_2(\ )$, and $\phi_3(\ )$ are well known and easily pictured from the resonance curve (it is assumed that the carrier is modulated by a single frequency for simplicity). Another case, namely, reflection from the Heaviside layer is mentioned by Mr. Ladner. Again it is simpler to consider I as the sum of its components, for the same reason that $\phi(\ )$ is a function of I.

The argument given by Mr. Ladner in favour of the "reality" of the components is futile. It is exactly analogous to the old argument "proving" that white light consists of trains of waves of all frequencies. All it shows is that a resonant circuit can be adjusted to make, say, $\phi_2(Y)$ large compared with $\phi_1(X)$ and $\phi_3(Z)$, *i.e.*, the result of the action of this circuit is to make a certain sideband so predominant that we may neglect the other components. We consider a current to be a real motion of electrons, hence the criterion whether a current is real or not should be whether the electrons move or not. Let i_1 and i_2 be any two steady currents, then $i_1 = (i_1 + i_2) + (-i_2)$; this is a mathematical identity exactly analogous to

$$I_0(1 + m \cos \omega t) \sin pt = I_0\{\sin pt + m/2 \sin (p + \omega)t + m/2 \sin (p - \omega)t\}.$$

In particular, when $i_1 = 0$ we have $0 = (i_2) + (-i_2)$, the physical interpretation of which is that zero current is equivalent to two equal currents flowing in opposite directions. We do not infer that the two currents actually flow. The heat developed in a resistance R is $\{i_2 + (-i_2)\}^2R = 0$, but if the two components really existed, the heat developed would be $\{(i_2)^2 + (-i_2)^2\}R = 2i_2^2R$, since the heat developed is merely the result of collisions which must accompany the flow. If we use the mathematical transformation $I_0(1 + m \cos \omega t) \sin pt = I_0\{\sin pt + m/2 \sin (p + \omega)t + m/2 \sin (p - \omega)t\}$ we must stick to the rules of the game, and work the problem out by mathematics, and must not introduce physical arguments like the collisions of electrons when half-way through the mathematics.

To sum up, we may only consider the modulated carrier as carrier and sidebands, TREATING EACH COMPONENT SEPARATELY, and adding the results, when mathematical analysis has shown it to be permissible. We may always consider it as an oscillation of "one definite frequency" but of varying amplitude, but in a great many cases it is difficult to picture the operation performed by a circuit or system on such an input—*e.g.*, reflection from the Heaviside layer. The operation performed by an oscillatory circuit is easily pictured, as Mr. A. B. Howe explained. Of course, we may always consider the modulated carrier as carrier and sidebands, if we operate on all the components as parts of the whole, but this usually entails working on paper and not in one's head.

W. B. LEWIS.

Abstracts and References.

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PROPAGATION OF WAVES.

ESSAI D'EXPLICATION DE L'ÉCHO STÔRMER-HALS (A Suggested Explanation of the Stôrmer-Hals Echoes).—H. S. Jelstrup. (*L'Onde Élec.*, December, 1928, pp. 538–540.)

As an alternative to Stôrmer's explanation, the writer suggested (*Norgenbladet*, 29th and 31st October, and 3rd November, 1928), that the long-time echo was due to the waves having made a large number of "bounces," between Heaviside layer and earth (perhaps far from the transmitter) and on other atmospheric layers, then concentrating themselves—more or less in phase—on the receiving station. "They may perhaps undergo also reflections and refractions in other layers higher than the ordinary layer. . . . We know, from the theory of fading, how the Heaviside layer changes its shape under the influence of sunlight, electrical conditions, aurora borealis, etc. At certain moments this layer may take shapes—curvatures—at different points such that they act as a kind of spherical mirror. The different parts could at the same time reflect the waves directly towards the receiving station, producing a maximum if there is phase agreement, a minimum if there is opposition. These effects of reinforcement interferences—partially a result of the variation of curvature of the layer—must be remembered in considering the Stôrmer echo." Finally, the writer calculates that after enough reflections to produce a 10 seconds delay, the strength of the echo (from Howes' formula) would be great enough to be audible on a good amplifying receiver.

ÉTUDE EXPÉRIMENTALE DES ZONES DE SILENCE DANS LA PROPAGATION DES ONDES COURTES (Experimental Study of the Zones of Silence in the Propagation of Short Waves).—R. Bureau. (*Comptes Rendus*, 4th February, 1929, V. 188, pp. 455–457.)

A paper based on a long series of maps representing conditions of reception of short waves, of various lengths, noted during 1927 and 1928 by an increasing number of observers, ending with 35 in France, 15 in other parts of Europe, and 8 in Africa. The following results are deduced from the hundreds of maps (not shown) :—the zones of silence practically never present a regular and symmetrical disposition round the transmitter: they can vary very greatly from one day to another: they do not always evolve in the same way along the scale of wavelengths: they prolong themselves into zones of weak audibility: they very often contain in their centre a zone of audition—sometimes variable, sometimes strong (but almost always homogeneous) of very varying extent—sometimes reaching hundreds of kilometres—and definitely *not* the zone of direct radiation. In some cases several successive rings (or crescents) of silence are observed, separated by rings (or crescents) of audition. Anomalous results, both positive and negative, are frequent. Transitory but vigorous effects of accidental causes are observed, at times acting on the whole band of wave lengths, at others on a very limited band only. The tests were made on two powers—150 and 300 w. to the aerial. "If the zones of silence are due to insufficient refraction, or some kindred phenomenon, and if absorption only plays a secondary part, the influence of the power on the limits of the zones would be very slight. Experience, on the contrary, shows that the above doubling of the power has a very marked effect in reducing the zones." It is quite definite that on some days the zones as a whole are more extended than on others—as if the ionised layers had increased in height. On other occasions, the extension of the zones only takes place in certain directions, as if the layers had taken on a slope. The writer is led more and more to the belief in a multiplicity of ionised layers, if only to explain the anomalies between one wave and another and the existence of the audition zones within the zones of silence. Finally, meteorological action is far from negligible, as can be seen from a comparison of the propagation maps with certain meteorological charts (those showing fronts and masses of air): he sums up by the following hypothesis :—" The ionised layers of the upper atmosphere play the principal rôle ; but—in certain critical conditions—a slight modification can decide between two possible and different paths along these layers. This modification may be the act of the phenomena of the troposphere, which would then become the arbiters of the propagation and would decide the fate of the wave."

THE ATTENUATION OF WIRELESS WAVES OVER TOWNS.—R. H. Barfield and G. H. Munro. (*Journ. I.E.E.*, February, 1929, V. 67, pp. 253–265, and Discussion to p. 270.)

Full version of the paper referred to in February Abstracts, p. 98. Interesting conclusions drawn from the tests are :—For transmissions confined to "town" areas only, consisting of offices, large buildings and residential districts without gardens, there is a very important increase of attenuation with frequency obeying approximately a fifth-power wavelength law, but there is no sign of any selective absorption due to receiving aerials. Over suburban areas only there is marked selective absorption, this effect being a maximum on a wavelength *just below* the wave to which the aerials are tuned. When the area traversed combines the two cases there are some indications that the steep attenuation/wavelength curve is combined with the selective absorption curve. These results are considered and theoretical grounds found for them.

BEMERKUNG ZU DEM AUFSATZ VON J. FUCHS: DAS VERHALTEN KURZER WELLEN IN UNMITTELBARER NÄHE DES SENDERS (A Note on Fuch's paper "The Behaviour of Short Waves in the Immediate Neighbourhood of the Transmitter").—P. O. Pedersen. (*Zeitschr. f. Hochf. Tech.*, February, 1929, V. 33, p. 66.)

Referring to the paper abstracted on p. 97, 1929, V. 6, the writer says: "The observed dependence of field-strength on lighting conditions, at small distances from the transmitter, is probably due either to partial reflection at surfaces of discontinuity, particularly in the higher, strongly ionised atmosphere, or to waves reflected by ground behind the skip zone." He refers to pp. 66, 136, 139, 213, 214 and 235 of his book "The Propagation of Radio Waves."

THE REFLECTION AND TRANSMISSION OF ELECTRIC WAVES AT THE INTERFACE BETWEEN TWO TRANSPARENT MEDIA.—H. M. Macdonald. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A, pp. 1–27.)

The writer obtains approximate expressions for the electric and magnetic forces in the transmitted and in the reflected waves, where electric waves are incident on the interface between two media, the surface of separation being any surface.

FORTPFLANZUNG DES LICHTES DURCH FREMDE KRAFTFELDER (The Propagation of Light Through Extraneous Fields).—V. Wisniewski. (*Zeitschr. f. Phys.*, No. 9/10, 1928, V. 50 pp. 644–647.)

ÉTUDE SUR LA PROPAGATION DES ONDES COURTES (On the Propagation of Short Waves).—
—. Guyot. (*L'Onde Élec.*, December, 1928, pp. 509–530.)

This paper is divided into two parts: in the first, the laws of propagation of short waves are considered, on the supposition that the Heaviside layer has its properties controlled simply by the position of the sun: the second deals with the alterations which must be made to those laws to allow for the rate of change of the ionisation at a point in the atmosphere: as a result of these modifications, what the writer calls "the Dynamic Theory of the Heaviside Layer" is reached. The lag between cause and effect in ionisation has the following results:—a lag in the appearance of signals at a given spot, behind the time calculated on the "classic" (static) theory—this lag varies with the distance and is of the order of several hours: a lag in the disappearance of the signals—this lag can be very considerable, and in certain cases (in the tropics) causes a disappearance of the silence zone: a decrease in the variations of the height of the layer as calculated on the static theory—this decrease is the more pronounced the stronger the sun's action. The paper includes graphs of observations on waves ranging from 33 to 82 m., some derived from Mesny's reports, others from tests in N. Africa. It ends by considering the limiting range (apart from reflection at the earth) for various wavelengths, as obtained from the critical angle of incidence $\left(\cos^{-1}\theta = \frac{\lambda}{75}\right)$ and the tangent to the earth from the layer. "At the equator it will be possible to have notable ranges with waves shorter than 10 m."—but only by day when the layer is low.

SOME POLARISATION PHENOMENA OF VERY SHORT RADIO WAVES.—E. A. Paulin. (*Phys. Review*, March, 1929, V. 33, pp. 432–443.)

A 5–7.5 m. wave transmitter, similar to that of Tykociner, is briefly described: also a "detector" (a complete portable receiving set, one triode and micro-ammeter) which "furnishes an excellent means for surveying a radiation field in the immediate vicinity of an oscillation generator, to establish its condition of polarisation. Furthermore, it may be used to measure the distribution of the field. . . ."

Tests resulted in the following conclusions:—"The loop of the oscillator, and the linear radiator coupled to it, imprint their character on the polarisation of the waves. That is, the wave is the resultant of components which have their source in the individual current-carrying elements in the radiating system. . . . Evidence of this is the modification of the field concomitant with the rotating of the loop and the directing of the linear oscillator." This seems to contradict the results obtained by Pickard, another of whose findings—that whatever the plane of the transmitter, reception was predominantly horizontal—is also contradicted here; for within the range considered (up to 100 metres) the type of polarisation showed no tendency whatever to change. This agrees with Austin and with Smith-Rose and Barfield.

Experiments with interference phenomena are described which illustrate the importance of secondary radiations from conductors, etc., near transmitter or receiver, which may affect materially the intensity or the polarisation of the total radiation received. The use of tuned rods for the formation of a beam is described, and illustrated by polar curves made with the apparatus.

RECEPTION EXPERIMENTS IN MOUNT ROYAL TUNNEL.—A. S. Eve, W. A. Steel, G. W. Olive, A. R. McEwan, and J. H. Thompson. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 347–376.)

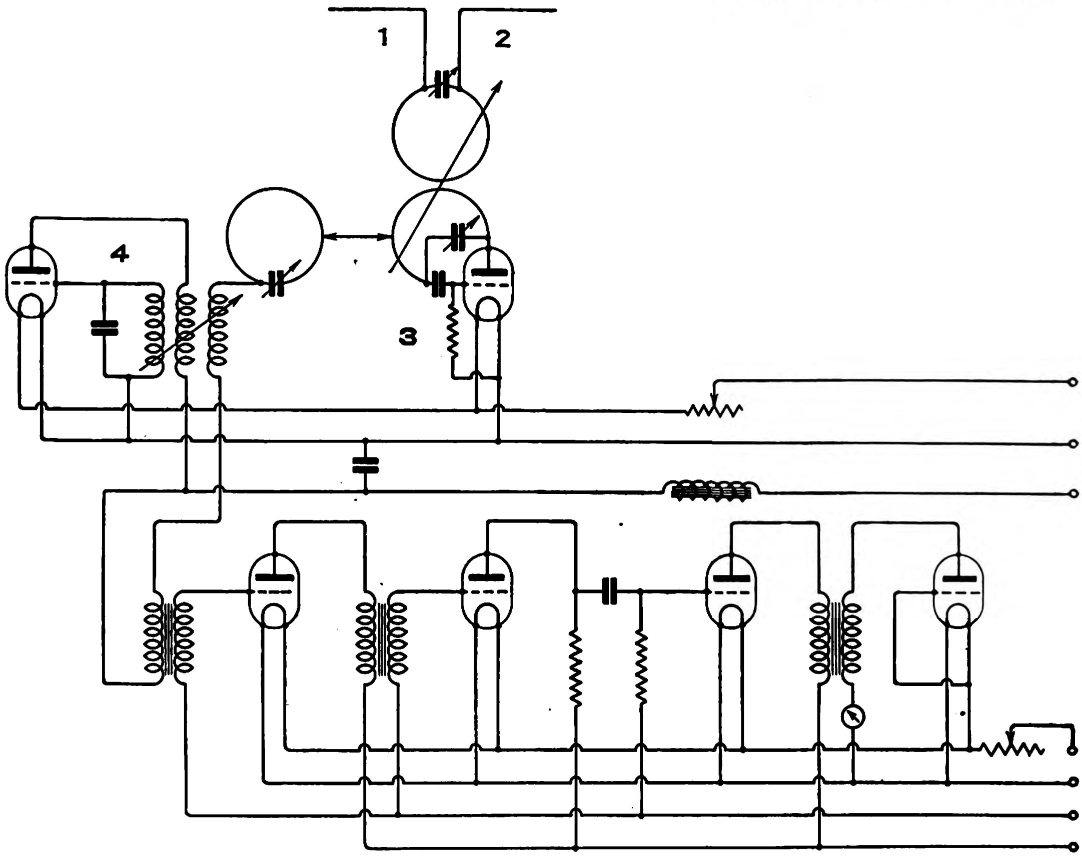
The tunnel is 3½ miles long; the mountain is for the greater part composed of limestone, but the entire centre portion—where it is highest—is of essexite. Tests were made on wavelengths round 50, 400, 1,400 and 17,000 m. The summarised conclusions are:—the penetration of any wave into the tunnel is some definite function of the wavelength: waves below 100 m. do not penetrate rock or soil to any appreciable extent: cables and rails do not conduct the short and broadcast waves to the same extent as they do the long waves—though their effect is appreciable on the broadcast band: wires and cables, when ungrounded, appear to act as wave antennæ—when grounded they act as loops: much more energy appears to enter *viâ* the tunnel mouth than was at first suspected, though the short waves do not

penetrate well or far into the tunnel even by this way of entry (*cf*. Ritz, tunnel results with very short waves, Abstracts 1929, V. 6, p. 150).

Abhängigkeit der Reichweite sehr kurzer Wellen von der Höhe des Senders über der Erde (Dependence of the Range of Very Short Waves on the Height of the Transmitter above the Earth).—H. Fassbender and G. Kurlbaum. (*Zeitschr. f. Hochf. Tech*., February, 1929, V. 33, pp. 52–55.)

Authors' summary: "The range of an aeroplane transmitter [3.7 m. wave] was measured in its dependence on height above ground. Subsequent tests on longer waves failed to show such relation, but the 3.7 m. wave displayed a close dependence. The ranges obtained with 1 watt power were distinctly less (even at great heights) than those obtained with the 'short' waves in general use, under similar conditions. Taking into consideration the present state of the technique of ultra-short wave reception, the ordinary short waves have a considerable superiority for general communication purposes. Whether there are possible uses for the ultra-short waves, for special purposes such as short-range bearings, remains to be seen."

The receiving circuit used is shown in the diagram—a super-regenerative receiver described by E. Busse (*Funkbastler*, p. 687, 1928) combined with L.F. amplifier, rectifier and measuring instrument—3 being an oscillating audion, 4 the super-regenerative valve; 1–2 is the dipole aerial. The height of the aeroplane varied from 50 to 2,700 m. The greatest range obtained (telegraphy) was about 125 km. All the ranges shown in the curves lie considerably below those calculated from the geometrical tangent; but in one test the receiver was raised 15 m. above the ground (to get rid of the effect of trees and buildings) and the range then agreed well with the calculated value. (*Cf*. Gerth and Scheppmann, April Abstracts.)



Mesure de l'Ozone de la Haute Atmosphère pendant l'Année 1928 (Measurements of the Ozone in the Upper Atmosphere during 1928).—H. Buisson. (*Comptes Rendus*, 25th February, 1929, V. 188, pp. 647–648.)

A continuation of the work at Marseilles carried out in 1927. As in that year, a main annual variation was found (a maximum of 375 in Spring and a minimum of 225 in Autumn), but less accentuated than in 1927. Irregular variations connected with movements of the atmosphere were

marked at the beginning and end of the year, but decreased in the Summer. The curve of annual variation is altogether similar in form to that at Arosa taken by a different technique. The amount of ozone has been slightly but definitely less in 1928 than in 1927.

EXPERIMENTELLE UNTERSUCHUNGEN ÜBER DIE DIFFUSION LANGSAMER ELEKTRONEN IN EDELGASEN (Experimental Investigation into the Diffusion of Slow Electrons in Inert Gases).—H. Pose. (*Zeitschr. f. Phys.*, 4th December, 1928, V. 52, No. 5/6, pp. 428–447.)

RECOMBINATION OF IONS IN ATMOSPHERIC AIR.—P. J. Nolan and C. O'Brolchain. (Short Summary in *Nature*, 2nd March, 1929, V. 123, p. 338.)

TWO ENERGY TYPES IN WAVE MOTION AND THEIR RELATION TO GROUP AND WAVE VELOCITY.—Lewi Tonks. (*Phys. Review*, February, 1929, V. 33, pp. 239–242.)

Author's abstract :—The energy of an element in a wave motion can be of two kinds : first, non-interactive like the energy of a set of independent pendulum bobs, and second, interactive like the potential energy of an element of a stretched string which is dependent only on the relative position of two neighbouring elements. In the former case the group velocity is zero, and in the latter it equals the wave velocity. The slowing down of energy transmission in intermediate cases is discussed qualitatively, and the ratio of group to wave velocity is calculated quantitatively in a number of cases on the assumption that the energy propagation is given not only by the product of energy density and group velocity, but also by the product of twice the interactive energy density and wave velocity. A general relation is suggested, without proof, for the connection between energy types and the ratio of group to wave velocity. The same ideas are applied to de Broglie's phase waves, the group velocity of which is the particle velocity.

LA PROPAGATION DE LA LUMIÈRE DANS L'ÉTHER (The Propagation of Light in the Ether).—H. Malet. (*Comptes Rendus*, 4th February, 1929, V. 188, pp. 443–445.)

Michelson's negative result leads to the statement "everything happens as though electromagnetic phenomena are exactly carried along with the earth's movement." The same applies to the phenomena due to the earth's gravitational field. If it is admitted that the electromagnetic and the gravitational fields both result from modifications of the same non-material medium (the ether) it is reasonable to see in the above-named agreement more than a coincidence, and to deduce from it a bond between the two groups of phenomena. The writer, therefore, postulates that "the velocity of light at a point of the ether is a (diminishing) function of the value of the gravitational potential at that point : in other words, the ether is—as regards the propagation of electromagnetic waves—an isotropic but not homogeneous medium." Besides defining the velocity at each point, it is necessary to define the "isokinetic" reference-system in regard to which the propagation takes place with the same velocity in all directions. The absence of inertia in the ether makes it illegitimate to assume (as is done in the majority of theories) that this medium itself forms the system of reference. The writer formulates as a second postulate : "the isokinetic system at a point M is determined by the condition that the value of the velocity c is the same at all points infinitely near to M ; *i.e.*, by the condition that grad $c = 0$." With these two simple hypotheses he accounts for the essential phenomena of the propagation of light : for an observer situated at the surface of the earth, the isokinetic system possesses an *ascending vertical* movement—hence Michelson's negative result, which would have been positive if his test had been made vertically (but only if the path employed had been very long)—*cf.* Corps, on Esclangon's results, Abstracts 1928, V. 5, p. 588. An approximate integration gives for the deviation of a light ray passing a star, at a distance R from its centre, the expression $2hm/c^2R$, which coincides with the Einstein formula when $h = 2$.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

A THEORY OF AURORAS AND MAGNETIC STORMS.—H. B. Maris and E. O. Hulburt. (*Phys. Review*, March, 1929, V. 33, pp. 412–431.)

Another paper on the "ultraviolet blast, high-flying atom" theory (see February Abstracts, p. 101). Among many other points brought forward as examples of known phenomena supporting their theory, the writers say that the blast "would be expected to cause changes in comets, much as it does in our own atmosphere, and we find that this actually happens . . . for in nearly every instance the date on which a comet was observed to undergo an unusual change, such as breaking up of the nucleus, loss of tail, sudden increase in brightness, etc., was found to follow, within a few days, the date on which a strong magnetic storm occurred on earth—provided . . . the earth and the comet were approximately on the same side of the sun."

THE ANALYSIS OF IRREGULAR MOTIONS WITH APPLICATIONS TO THE ENERGY-FREQUENCY SPECTRUM OF STATIC AND OF TELEGRAPH SIGNALS.—G. W. Kenrick. (*Phil. Mag.*, January, 1929, V. 7, No. 41, pp. 176–196.)

In his work on the spectrum of static and the limitations to the advantages to be gained by the use of linear selective circuits for the elimination of interference, Carson considers a function $R(\omega)$ measuring the energy of interference on the frequency corresponding to ω ; this function he considers to be a continuous finite function converging to zero at unity, and everywhere positive, but he does not study in detail its form for various types of random disturbance. This paper indicates a method by which its form may in certain cases be computed. The method is of general application, but the specific examples chosen are suggested by the researches of Appleton and Watt : pulses disclosing an $R(\omega)$ varying over a wide range directly with the square of the wavelength. It

seems probable that such a relation applies to the types of disturbances important in static—except, of course, inductive interference from power lines, etc. The method here described introduces a formula due to Wiener, by means of which it is possible to obtain a function $\theta(\omega)$ such that $\theta(\omega) = \int_0^\omega R(\omega)d\omega$.

The graph of $\theta(\omega)$ against ω, for a function having predominantly but not entirely random characteristics, is such that the rise between any two ω's is proportional to the energy in the spectrum of $f(t)$ over that region; moreover, whenever there is a "line" in the $f(t)$ spectrum (or a truly periodic disturbance of finite energy) there is a sharp perpendicular rise in $\theta(\omega)$. Having shown how to analyse irregular motions defined over a *finite* interval by means of a graph or other set of data, the writer goes on to show how the same formulæ can be employed to characterise irregular motion analytically defined by probability conditions over an *indefinite* time: using the Poisson exponential binomial limit and applying it to automatic telegraph signals of square wave-form and alternately of opposite sign, after justifying the treatment of these as random pulses rather than as the sequence of equally spaced dots assumed by other investigators. Then by making certain adjustments he applies his results to the frequency spectrum of static (square wave-form, or exponential: chance alone determining the signs); coming to the conclusion that the energy due to gross outline of such pulses, of the order of 10^{-8} sec. in duration, can produce appreciable fields (proportional to the square roots of the energies) on the longer wavelengths employed in practice; but that on the shorter wavelengths pulses or ripples of smaller energy content but shorter duration will be increasingly important. The methods employed are useful also in the harmonic analysis of many other types of irregular motions, such as voice waves or noise.

ON THE NATURE OF THE IONS IN AIR.—H. A. Erikson. (*Phys. Review*, March, 1929, V. 33, pp. 403–411.)

Results are given showing the production and ageing of the initial positive ion in dried air and dried nitrogen; also showing that when the final positive air ion of mobility 1.36 is passed into moist air the final ions disappear and a swifter 1.87 ion appears. Results are also given showing that these in turn change back into a 1.35 ion. The interpretation given of the above is that a neutral H_2O molecule gives up an electron to the final 1.36 two-molecule positive ion, thus giving a one-molecule positive ion which has a higher mobility. This H_2O^+ ion ages by attaching itself to another molecule forming a slower 1.36 ion. The article closes with a statement of the reasons for the author's view that the initial and final positive ions are respectively one and two molecules large. *Cf.* an earlier paper, March Abstracts, p. 147.

NUOVO REGISTRATORE DI ATMOSFERICI E PRIMI RISULTATI CON ESSO OTTENUTI (A New Atmospherics Recorder, and Its First Results).—I. Ranzi. (*Nuovo Cim.*, August/October, 1928, V. 5, pp. 326–330.)

The recorder, in which a very sensitive superheterodyne receiver controls a neon lamp, records continuously on a photographic film. Results of a 2,000 hours' run are said to confirm Bureau's conclusions as to the classification and origins of atmospherics. (Abstracts, 1928, V. 5, p. 684.)

ON THE VARIABILITY OF THE QUIET-DAY DIURNAL MAGNETIC VARIATION AT ESKDALEMUIR AND GREENWICH.—S. Chapman and J. M. Stagg. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A, pp. 27–53.)

THE ENERGY OF LIGHTNING.—A. McAdie. (*Monthly Weath. Rev.*, June, 1928, V. 56, pp. 216–219.)

The results obtained by Peek, C. T. R. Wilson, Simpson and others are considered. Blue Hill Observatory results on the fusion of kite wires indicate voltages of the order of 1.3×10^7 v. and energies of the order of 11 kwh. The importance of a study of the side discharges or split-off flashes is stressed.

SUR L'ÉLECTRICITÉ ATMOSPHÉRIQUE AU COURS DES VENTS DE POUSSIÈRE DU NORD DE LA CHINE (Atmospheric Electricity during the Dust Winds of N. China).—H. Pollet. (*Comptes Rendus*, 28th January, 1929, V. 188, pp. 406–409.)

Wind velocity is about 10-15 m. per sec.; diameter of particles about 34μ; number of particles per c.c. from 5–42. The particles are negatively charged, with a mean charge of about 4.4×10^{-8} e.s.u.—that is, about 100 times the charge of an ion. The height of the layer of air containing the particles is about 50 m. During the wind, the electric field is reversed and about 20 times stronger than it is normally. Before, during and after such a wind, atmospherics are very numerous; 17 per minute have been counted.

ACCUMULATION OF ELECTRIC CHARGE ON THUNDERCLOUDS.—D. Nukiyama. (*Jap. Journ. Astron. & Geophys.*, No. 1, 1928, V. 6, pp. 63–69.)

A NOTE ON THE DIRECTIONAL OBSERVATIONS ON GRINDERS IN JAPAN.—E. Yokoyama and T. Nakai. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 377–379.)

The U.R.S.I. paper dealt with in Abstracts, 1928, V. 5, p. 684.

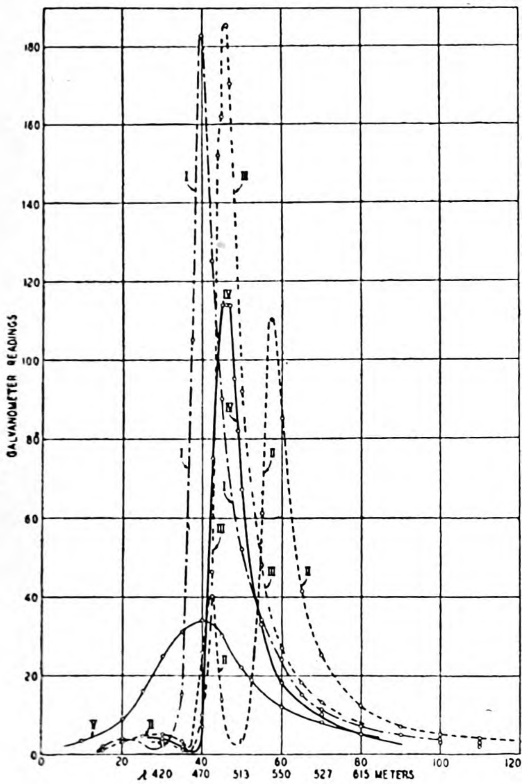
RADIUM EMANATION CONTENT OF THE ATMOSPHERE AS DETERMINED BY AEROPLANE OBSERVATIONS.—A. Wigand and F. Wenk. (*Ann. der Physik.*, 28th July, 1928, V. 86, pp. 657–686.)

PROPERTIES OF CIRCUITS.

FILTERING ANTENNAS AND FILTER-VALVE CIRCUITS.—J. Plebanski. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 161–173.)

Author's summary:—" Some methods of coupling together many circuits or antennas, giving them simultaneous excitation from the same source of energy, are described. The purpose of such arrangements is the construction of practical filter circuits (filtering antennas) giving square-topped resonance curves with good efficiency. Some interesting

phenomena with coupled antennæ are described." After referring to Vreeland's filter circuits with square-topped curves for the distortionless reception of modulated waves, the author describes his own methods, by which the time of the disappearance of the transitory condition is made shorter than in ordinary series band filters. Taking the case of two antennæ or loops coupled together, and plotting their power-absorbed/frequency curves, he shows that the mutual coupling of the two circuits reduces the resistance of the first



circuit, which receives energy not only from the incoming wave but also from the second circuit. The efficiency can be 90 per cent. or more, while the overall efficiency of a series filter is only about 50 per cent. Taking the case of a variable frequency of wave and constant tuning, for an arrangement of three frame aerials coupled according to his method, he describes the procedure of his tests. The second and third frames are removed and curve V (see diagram) is taken—the ordinary resonance curve. The second frame is then coupled with the first and adjusted to give maximum current in the first frame for its own resonance wavelength. The third is then added and adjusted to give still more current; the curve for the current in the first frame is then taken—curve I. Then the second and third frames are slightly detuned by changing their capacities about ± 3 per cent. respectively. The resulting curve has two maxima—curve II. By diminishing the detunings, curve IV appears and the square-topped filter action is obtained, a band approximately 20,000 cycles wide being received with uniform intensity, while frequencies outside this band are strongly damped—curve IV going below curve V at each side. If the detunings are decreased still further, curve III—similar to a normal resonance curve—is obtained. "It is obvious that with five or more circuits still better results can be obtained." If the second and third frames have their resistances reduced to zero by reaction, an "inverted resonance curve" results. The author ends by describing the use of such coupled circuits for multiplex transmission, and by showing various ways of employing them as intervalve filters with flat-topped resonance curve or some other curve suitable for a particular purpose of transmission or reception.

THE VALVE AS AN ANODE BEND DETECTOR: OBTAINING MAXIMUM EFFICIENCY WITH LARGE INPUTS.—W. I. G. Page. (*Wireless World*, 13th and 27th March, 1929, V. 24, pp. 279–283 and 326–329.)

This method of detection has now attained a new importance owing to broadcasting and the need for selectivity and high-quality reproduction, and to the advent of new valves specially suitable for it. Among other points in the first instalment, the effect of percentage modulation at the transmitter is discussed; it is mentioned that at present the maximum peak modulations of 2LO, 5GB and 5XX are 80, 100 and about 85 per cent. respectively.

DYNAMIC RESISTANCE: THE TUNED CIRCUIT IN ITS RELATIONSHIP TO RECEIVER DESIGN.—A. L. M. Sowerby. (*Wireless World*, 13th March, 1929, V. 24, pp. 274–278.)

For the calculation of the H.F. amplification afforded by a receiver at different wavelengths, the high frequency resistance ("equivalent series resistance" r) of the tuned circuit is not used directly, its place being taken by the "dynamic" resistance ("equivalent parallel resistance" R). In this article the relationship of r and R is discussed non-mathematically, and the use of the equation $R = \frac{L}{Cr}$ in the amplification calculations is shown.

NEUTRALISATION DES RESONANZ-VERSTÄRKERS (Neutralisation of the Resonance Amplifier).—K. Schlesinger. (*Zeitschr. f. Hochf. Tech.*, February, 1929, V. 33, pp. 63–66.)

If the anode of a valve is loaded with a circuit of L and C in parallel which is tuned to the frequency of a similar input grid circuit, oscillations are set up just as in the Huth-Kühn oscillator circuit: *i.e.*, as a result of the coupling due to the grid-anode capacity. To suppress this self-excitation, a compensating current must be arranged to flow by a second path from the input circuit to the loading circuit, so as to produce at the neutralising points of the latter an A.C. potential equal in frequency and amplitude but displaced in phase by 180°. The

action of the well-known three-point neutralising circuit is readily understood by representing it as a bridge-circuit, but Hazeltine's classic Neutrodyne circuit cannot be explained on these lines. In the present paper the equivalent circuit of the Neutrodyne arrangement is considered, the Ohm-Kirchoff equations derived, and an expression found for the value of the neutralising capacity. The dependence of this on the frequency is shown; as a way of getting rid of this dependence, taps (for the neutralising path) on *both* circuit-inductances are indicated. Experimental verification of some of the calculations is given.

CIRCUIT ANALYSIS APPLIED TO THE SCREEN-GRID TUBE.—J. R. Nelson. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 320–338.)

Author's summary: "General radio-frequency circuit theory is discussed in this paper. The theoretical work and discussion is divided into two parts, amplification and stability.

"General amplification equations for impedance and transformer coupling, using an untuned primary whose period is above the highest frequency considered, are derived and discussed for the case of a screen-grid tube such as Cunningham type CX–322.

"Feedback through the mutual capacity plate to grid capacity is also considered. A general expression for the limit of stable amplification per stage is inferred for n stages from the expressions found for one and two stages. This general expression $Av. < \sqrt{2gm/nwc_0}$ is in terms of the mutual conductance, total grid to plate capacity, frequency and number of stages."

NOTE SUR LES TRANSFORMATEURS INTERMÉDIAIRES DE BASSE FRÉQUENCE (Note on Inter-valve L.F. Transformers).—P. K. Turner. (*L'Onde Élec.*, December, 1928, pp. 541–542.)

Jouaust's article (January Abstracts, p. 41) says that to avoid the parallel resonance due to the action of the magnetising current, by shifting it to the high regions of the frequency spectrum, the inter-winding capacity should be reduced as much as possible by a suitable design of spool and winding. The writer points out that in England it was found impossible to reduce this capacity enough to put the first resonance above 2,000 p.p.s., but that by employing valves of low anode resistance this resonance was made imperceptible, while at the same time—by reducing the leakage flux—the second resonance only occurred in the highest frequencies. Jouaust replies (p. 542) that when he wrote his paper, only high resistance valves were readily available in France.

ON THE BEHAVIOUR OF NETWORKS WITH "NORMALISED" MESHES.—E. A. Guillemin and W. Glendinning. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 380–393.)

Authors' summary: "The theory of normalising meshes in electrical networks, as outlined in a recent article appearing in this journal (Abstracts, 1928, V. 5, p. 33), is verified and illustrated by examples and figures relating to two- and three-mesh circuits. In the two-mesh circuit mesh No. 1 was normalised, thus confining the corresponding frequency to that mesh both for the transient and steady states, as illustrated by Figs. 2 to 6 [graphs and oscillograms]. For the three-mesh circuit meshes Nos. 1 and 3 were normalised, and the results are illustrated in Figs. 6–16 inclusive. In each case the theory was checked in every detail." They conclude by pointing out that it is safe to assume that the theory holds in its general form and applies to any type of network however complex. "It seems reasonable that these properties of isolation and suppression of resonance effects should have some practical application in the design of circuits with special characteristics."

A NEW TRANSFORMATION IN ALTERNATING CURRENT THEORY, WITH AN APPLICATION TO THE THEORY OF AUDITION.—B. van der Pol. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 477–488.)

So long as positive resistances only were known, the *real* part of an impedance was always positive; but with the advent of negative resistances (*e.g.*, arc, dynatron, or triode with reaction), the real part of an impedance—like the imaginary part—may have both signs. The transformations here considered (which may be called j-transformations) consist in multiplying all complex impedances of a network by j, j^2, j^3 and j^4 respectively. Examples of well-known circuits, thus treated, are given; in particular a circuit is obtained with the valuable property that the amplitude of the current is unaffected by the value of R (the resistance), but its phase is affected, so that the phase can be changed over 180° without affecting the amplitude. This circuit is applied experimentally to verify Ohm's acoustic law that the human ear perceives, from a complicated sound, the amplitudes of the various components only—that it cannot recognise changes in phase of these components. This law was found to be valid for periodic sounds (such as vowels) and normal amplitudes; for aperiodic sounds (the spoken word) it holds good so long as the relative phase retardation between high and low components is not greater than 360°.

DIE MAGNETISCHE FELDSTÄRKE IN DER EBENE EINER STROMDURCHFLOSSENEN KREISFLÄCHE (The Magnetic Field Strength in the Plane of a Circular Surface Traversed by a Current).—L. Fleischmann. (*Arch. f. Elektrot*, V. 21, 1928, p. 30.)

ON NEGATIVE RESISTANCE.—M. A. Bontch-Bruevitch. (*Teleg. i Telef. b. Prov.*, Nichny Novgorod, October, 1928, V. 10, pp. 572–586.)

TRANSMISSION.

DIE ERZEUGUNG KÜRZESTER ELEKTRISCHER WELLEN MIT ELEKTRONENRÖHREN (The Production of the Shortest Electric Waves by Valves).—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, February, 1929, V. 33, pp. 66–74.)

The first part of this survey was dealt with in April Abstracts. This second part deals with the production of oscillations by the control of the electron movements by brake-fields. (1) Whiddington's pioneer work: Electron oscillations of

Barkhausen-Kurz: the wavelength formula

$$\lambda = \frac{1000 d_a}{\sqrt{E_g}} \cdot \frac{E_g - d_g E_a}{E_g - E_a},$$

d_g and d_a being diameters of grid and anode: working independently, with ordinary three-electrode valves, Zilitinkewitsch obtained similar oscillations and—also from the path-times of the electrons—arrived at a somewhat similar formula which agreed well with his results on 40 and 70 cm. waves: the dependence of electron oscillations on the gas pressure—Scheibe, Nettleton, Pierret, Grechowa, Kapzov: the influence of the space charge—Barkhausen-Kurz, van der Pol, Gill, Kapzov and Gwosdower: the influence of a coupled circuit—Gill and Morrell, Sahanek and others, the oscillator of Tank and Schiltknecht, Wechsung (with A.C. feed), Kohl. (2) The simultaneous appearance of B.-K. and G.-M. oscillations—Tank, Kapzov and Gwosdower, Hollmann. The work of most of the workers quoted above is illustrated by curves or other diagrams. The paper will be concluded by a third part.

VACUUM TUBES AS OSCILLATION GENERATORS.—D. C. Prince and F. B. Vogdes. (*Gen. Elec. Review*, December, 1928, V. 31, pp. 678–683.)

This seventh instalment of the series deals with methods of improving the efficiency of valves driving oscillating circuits. With sinusoidal waves under good operating conditions, the alternating voltage has a peak value slightly less than the direct voltage of the supply source, and if the plate current is drawn only at the time of minimum plate potential, power conversion occurs with high efficiency. In practice, however, such operation is not desirable since full use is not being made of the capabilities of the valve; accordingly, efficiency of conversion is relinquished to get more output from the same apparatus, by allowing the plate current to flow through a longer period of time. The additional power thus obtained is produced at a much lower efficiency than the first. The paper considers alternative plans to avoid this loss of efficiency: increasing the instantaneous value of current flow while the plate voltage is near its minimum: control of the plate-voltage wave by adding harmonics, to produce a flat or slightly cupped wave—with increase of output and decrease of loss (an "harmonic trap" circuit is described which effects this): a high efficiency circuit with square current wave. The causes and prevention of parasitic oscillations are discussed.

MESSUNGEN AN KURZWELLENRÖHREN (Measurements on Short Wave Valves).—H. Hornung. (*Ann. der Phys.*, 25th February, 1929, 5th Series, V. 1, No. 4, pp. 417–456.)

A quantitative investigation of the arrangements used by Kohl (see the next two abstracts) for the production of waves below 1 m. Among other results, the wavelengths are found to be dependent not only on the circuit constants but also on grid and anode potentials and on the emission current; the dependence on these, however, diminishing with diminishing wavelength. Results by no means agree with the theory of Barkhausen-Kurz and Scheibe.

For a given circuit, increasing emission (with constant anode and grid voltages) causes λ to decrease almost linearly. Increasing grid voltage (with constant emission and anode voltage) causes λ again to decrease almost linearly. Increasing anode voltage (with constant emission and grid voltage) causes λ to increase almost linearly. The valves will oscillate with isolated anodes, wavelengths then being somewhat smaller: for a constant wavelength, very sudden and intense amplitude maxima (as the emission current was varied) were noted: these are not yet explained. The author mentions that preliminary efforts at arc-production of very short waves were unsuccessful.

ÜBER KURZE UNGEDÄMPFTE ELEKTRISCHE WELLEN (On Short Undamped Electric Waves).—K. Kohl. (*Zeitschr. f. tech. Phys.*, December, 1928, pp. 472–475.)

An earlier paper on the same subject was dealt with in Abstracts, 1928, V. 5, p. 464. The author's interpretation of his method of producing 30–90 cm. wavelengths is that the electron stream in the grid-anode gap excites the oscillatory circuit to oscillate at the latter's own frequency, whereby the electron stream in its turn is controlled by the oscillating voltage between grid and anode. The difficulty, that the frequency is nevertheless dependent on working conditions, is explained by the supposition that the electron-gas between grid and anode has a dielectric constant less than unity, the difference becoming greater the more dense the electrons. On this supposition he shows that all the observed results naturally follow. This explanation he applies also to the Barkhausen-Kurz oscillations, in opposition to the purely "electron-oscillation" idea of those workers.

NEUE ERFAHRUNGEN BEI ELEKTRISCHEN KURZWELLEN (New Experiments with Short Waves).—K. Kohl. (*Verh. d. Deut. Phys. Ges.*, No. 2, 1928, V. 9, pp. 36–37.)

A theory of the dependence of wavelength on working conditions, in the generation of oscillations by grid-excitation of small circuits. The wavelength is linked to the dielectric constant of the electron-gas forming the dielectric in the grid-anode capacity. According to Einstein, this dielectric constant $\epsilon = 1 - \text{const.}\ n.\lambda^2$, where n is the mean electron density in the grid-anode space. The theory fits in with experimental results.

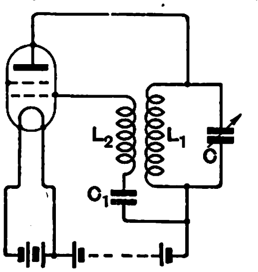
EXPERIMENTELLE UNTERSUCHUNGEN ÜBER DIE BARKHAUSEN-KURTZSCHEN SCHWINGUNGEN IN MAGNETISCHEN FELDERN (Experimental Investigations of the B.-K. Oscillations in Magnetic Fields).—M. Forró. (*Ann. der Phys.*, 25th February, 1929, 5th Series, V. 1, No. 4, pp. 513–528.)

With different valves three different "classes" of oscillation, differently affected by magnetic field changes, were found. Full details are given.

Über die Instabilität der Frequenz von Röhrengeneratoren und deren Stabilisierung (The Frequency-instability of Valve Generators, and their Stabilisation).—W. Lazaref. (*Zeitschr. f. Hochf. Tech.*, February, 1929, V. 33, pp. 55–63.)

Author's summary:—" The mechanism of the frequency changes of valve generators due to alterations in heating current, anode potential, and coupling, is here elucidated. The cause lies in the grid-current, whose A.C. component acts on the oscillating circuit and increases the damping factor; this increase produces a phase difference between the A.C. components of the anode current and of the anode potential, and this leads to a change of frequency.

" A stabilised generator has been constructed which keeps its frequency constant with a sufficient accuracy, namely:—the frequency variation is less than 0.003 per cent. for a change of heating current from its lowest (40 mA.) to its maximum (75 mA.): for a ten-fold change of anode voltage from 100 to 10 v., the frequency variation is less than 0.0001 per cent." In the particular circuit set up by the writer, frequencies can be chosen between 435 and 3×10^6 p.p.s. The method (patented in Russia in 1927) is shown in the diagram.



The control grid is left free. The condenser C_1 (in the space-charge grid circuit) can be varied between 0.01 and 2μF. The stabilisation is the more perfect the smaller the conductivity of this condenser. In the particular case considered, the ohmic resistance of C_1 and the resistance of the valve holder are each 100 megohms; even for a small current, the grid receives a negative charge. The grid-current, at the setting-in of oscillation, is about 10^{-6} A., and the grid obtains a considerable negative charge. Oscillation takes place only in the negative region of the characteristic; only a purely capacitive current flows in the grid (the capacity of the system grid-cathode may reach 10 cm.). Under these conditions the generator current is a pure or nearly pure sine wave: no harmonics can be detected. Loose coupling is essential: too tight a coupling produces irregularity. The whole generator, or at least the inductances, must be electrostatically screened; otherwise the external fields may induce such a negative charge on the grid that no oscillations can take place. The advantage of using a two-grid valve appears to be due to its small " durchgriff " ($1/\mu$); the second grid appears to play no part.

Hand Generator (40-Watt) with Automatic Signalling. (*Wireless World*, 27th February, 1929, V. 24, p. 226.)

In an article " Radio at the British Industries Fair," a generator shown by the M.L. Magneto Syndicate is described, the output of which is stated to be 40 w., the handle being turned by one hand. Incorporated in the casing is the Frost automatic signalling device, on whose disc the studs can be arranged for any pre-arranged signal; so, for example, in use in outlying places, a call for a doctor would be sent out again and again so long as the handle continued to be turned.

Investigation of the Stabilisation of a Short Wave Oscillator with Negative Resistance by Means of a Special Stabilising Electromotive Force.—P. N. Ramlau. (*Teleg. i Telef. b. Prov.*, Nichny Novgorod, October, 1928, V. 10, pp. 514–529.)

Dependence of the Range of Very Short Waves on the Height of the Transmitter above the Earth.—H. Fassbender and G. Kurlbaum. (*See under* " Propagation of Waves.")

RECEPTION.

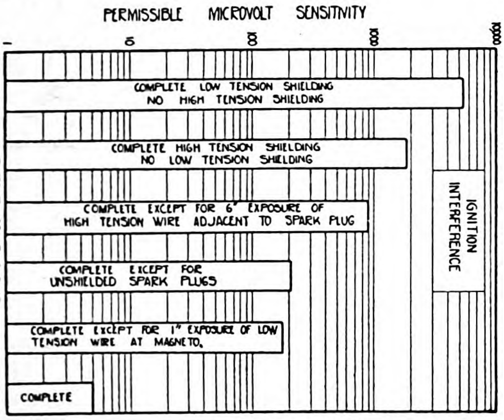
An Aircraft Radio Receiver for Use with Rigid Antenna.—F. H. Drake. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 306–319.)

Author's summary: " An outline is given of the physical and electrical requirements of an aircraft radio receiver suitable for the reception on a rigid antenna of radio beacons and weather service. The design of a special unicontrol receiver calculated to fulfil these requirements is described. Quantitative performance data are presented, with particular attention to the problem of detector overloading when operating a visual indicator from a beacon of the Bureau of Standards type. The corroboration of these data by practical tests is briefly discussed. The paper is concluded with quantitative discussion of the problem of ignition shielding on a particular type of airplane motor."

Regarding the method of detection, the paper mentions that a detector capable of withstanding considerable overloading is provided by the use of anode rectification with automatic grid bias (Ballantine); this feature being particularly important in connection with the visual beacon indicator (see recent Abstracts). It also has other advantages:—though it is commonly supposed that grid rectification gives greater sensitivity than anode, the micro-volt sensitivity of the tetrode receiver described is twice as great with anode detection as with grid, although the small-signal detection factor for the latter is about three times as great as for the former. " Plate detection exceeds grid rectification in this case because it leaves unaffected the ratio gain of the preceding stage, whereas due to electronic conductance grid detection reduces this gain by a factor greater than 2 to 1. For the same reason the selectivity is considerably greater with plate rectification than with grid rectification. The higher output impedance resulting from plate detection does not impair the uniform transmission of low modulation frequencies essential for the visual beacon provided the coupling between detector and audio amplifier is properly designed."

The diagram reproduced gives the relation between the permissible receiver sensitivity (to render ignition interference just audible) and the degree of shielding, in an aeroplane equipped with a single Wright Whirlwind motor; the results must of

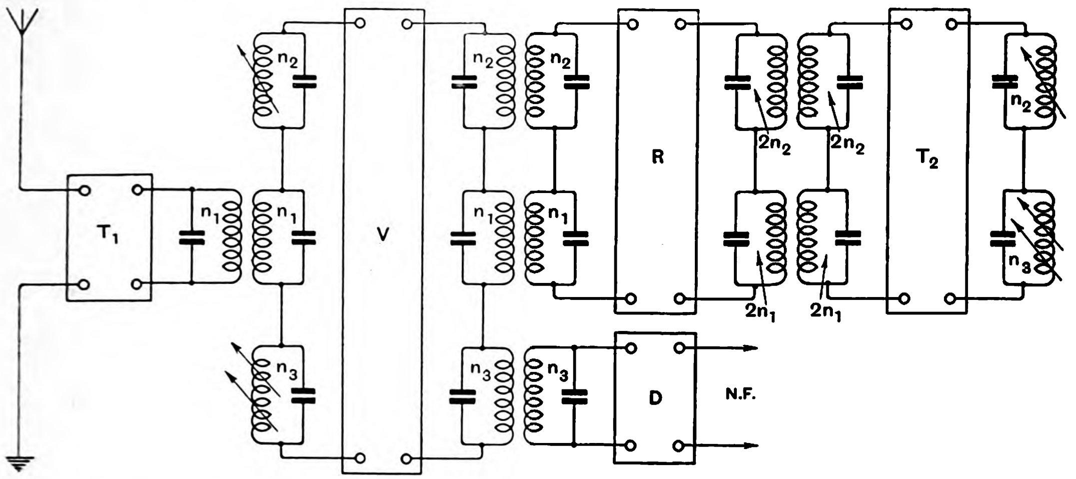
course be applied with caution to other installations, but the relative magnitudes of the various factors contributing to the total disturbance are of general interest.



DAS PROBLEM DER ÖKONOMISCHTEN VIELFACH-TRANSPONIERUNG (The Problem of the Most Economic Multiple Frequency-Changing Reception).—F. Aigner. (*Zeitschr. f. Hochf. Tech.*, February, 1929, V. 33, pp. 47–52.)

This second and final part of the paper referred to in April Abstracts deals with apparatus with increased sharpness of selection :—(a) for unmodulated waves, with the help of a single fixed-frequency local generator and the use of frequency-multiplication. The obtaining of freedom from interference by repeated frequency-doubling alone is limited by the speedy arrival at the short wave region and the need for impracticable decrements ; it is therefore only applicable to telegraphy on very long waves. This difficulty is avoided by the alternate use of frequency-doubling and frequency-transposing by heterodyne. In an example given, a first difference-frequency of 75,000 is obtained from the incoming signal by means of an input frequency transposer "of variable frequency" : it passes through a frequency-doubler and becomes 150,000 ; subtracted from the fixed transposing frequency (250,000) it yields 100,000 which is then doubled by the same doubler to 200,000. This, transposed by the 250,000 frequency, gives 50,000. These particular frequency-changes are supersonic, but this is not essential. Unfortunately, the method is not applicable to modulated waves, but these are dealt with in (b) :—the use of a single fixed local frequency with the help of special Helmholtz combination-frequencies. The diagram below shows the lay-out of such a multiple wave-change, frequency doubling circuit with reflex connection.

T_1 is the variable input frequency-transposer, T_2 the fixed transposer of frequency ν. V represents an intermediate-frequency reflex amplifier for amplifying the frequencies n_1, n_2 and n_3 (see later) ; R is the wave-change rectifying amplifier, and D is the output demodulator. The method depends on the utilisation of suitable members of the group of Helmholtz combination tones formed by the demodulation of a carrier wave of frequency H with its side-bands $H \pm N$. The choice lies between those possessing the form aH and $aH \pm N$ (a being a whole number) and a suitable value for a is 2 (giving a long wave) ; the method adopted is to use a rectifier-amplifier whose anode circuit is tuned to $2H$. The idea of increasing selectivity by the use of frequencies $2H$ and $2H \pm N$ was originally suggested by Grimes, for his "octamonic" receiver using frequency doubling ; but even for the longest broadcast waves only one stage was possible. With the present method several stages are possible.



The first difference-frequency n_1 (obtained from the signal and the variable-frequency input heterodyne) is passed through the rectifying amplifier R which selects, out of the resulting complex Helmholtz combination tones, the frequency $2n_1$ by means of its tuned anode circuit. This then combines with the fixed frequency ν of the transposer T_2, giving n_2 ($= \nu - 2n_1$) which is returned to R, leading to the selection of $2n_2$ and finally to

the production of n_3 $(= \nu - 2n_2)$. The various values are selected with attention to the frequencies of the principal interfering stations. A later paper will deal with the practical design of these two types of receiver (for which patents are being taken out).

RECEIVING SETS FOR AIRCRAFT BEACON AND TELEPHONY.—H. Pratt and H. Diamond. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 283–305.)

A reprint of the Bureau of Standards paper dealt with in April Abstracts.

THE PERFORMANCE OF VALVE DETECTORS.—W. B. Medlam and U. A. Oschwald. (*J. Inst. Wireless Tech.*, March–June, 1928, V. 1, pp. 147–223.)

A record of experiments carried out to determine the audio-frequency efficiency of, and the nature and magnitude of various forms of distortion which may be introduced in, a triode detector stage using a high external anode resistance. The effects on the performance of the following factors are considered: magnitude of external resistance, shunting capacity, amplification factor, method of rectification (grid or anode circuit), input voltage, and modulation depth. Experimental results are also given for the determination of optimum working conditions, and for the relation between D.C. change in anode current and audio-frequency output. Some account is also given of measurements made with a triode with neutralised space charge used as a diode. The paper contains a number of experimental results which should prove useful for correlation with analytical investigations. The most outstanding result is perhaps that a considerable degree of output-modulation frequency variation can arise with resistance loads in the anode circuit, if there is shunt capacity across the resistance.

THE RECEIVING SYSTEM FOR LONG-WAVE TRANS-ATLANTIC RADIO TELEGRAPHY: DISCUSSION.—(*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 174–184.)

Discussions following the paper referred to in April Abstracts.

DIE UMÄNDERUNG VON BATTERIE-EMPFÄNGERN AUF HEIZUNG MIT WECHSELSTROM OHNE UMBAU DES EMPFANGSGERÄTS (Changing-over Battery-supplied Receivers to A.C. Filament Supply without Dismantling).—(*Rad. f. Alle*, January, 1929, pp. 11–13.)

A description of the use of Telefunken adapters—A.C. valve holders plugging into the ordinary sockets. The A.C. sockets lead out by terminals at the side, which are connected to additional bus-bar leads going to the heating-current transformer.

RECEPTION AND RETRANSMISSION ON THE SAME ANTENNA.—V. A. Pavlov. (*Teleg. i Telef. b. Prov.*, Nichny Novgorod, October, 1928, V. 10, pp. 552–555.)

A METHOD OF DIMINISHING INTERFERENCE IN RADIO TELEGRAPHY.—G. A. Ostroumov. (*Teleg. i Telef. b. Prov.*, Nichny Novgorod, October, 1928, V. 10, pp. 530–535.)

SUPER-REGENERATIVE RECEIVER FOR ULTRA-SHORT WAVES.—Fassbender and Kurlbaum. (*See under* "Propagation of Waves.")

AERIALS AND AERIAL SYSTEMS.

INVESTIGATIONS ON WIND PRESSURE ON POLES AND CABLES FOR OVERHEAD TRANSMISSION LINES.—(*Journ. I.E.E.*, February, 1929, V. 67, pp. 229–240.)

Technical Report of the British Electrical and Allied Industries Research Association.

OVERHEAD ELECTRIC LINES.—W. B. Woodhouse. (*Journ. I.E.E.*, February, 1929, V. 67, pp. 217–228, and Discussion, pp. 241–252.)

An account of the work of the British Electrical and Allied Industries Research Association.

ON THE CALCULATION OF THE RADIATION OF DIRECTIONAL ANTENNÆ: AND ON THE RADIATION OF A SIMPLE ANTENNA IN THE PRESENCE OF A REFLECTING WIRE.—A. Pistolkors. (*Teleg. i Telef. b. Prov.*, Nichny Novgorod, October, 1928, V. 10, pp. 540–551.)

VALVES AND THERMIONICS.

CONTROL OF CURRENT IN A DISCHARGE-TUBE BY MEANS OF A MAGNETIC FIELD.—R. F. Earhart and C. B. Green. (*Phil. Mag.*, January, 1929, V. 7, pp. 106–115.)

Plane parallel brass plates at ordinary temperatures were used as electrodes, in air (and hydrogen) at pressures ranging from 0.80 to about 9.0 mm. Hg. With d (mm. between plates) equal to 15 or more, a longitudinal field (1,000–1,800 gauss) produced an increase in current but only a small one, especially for a current of several mA. If d was reduced to the order of 1, and the pressure properly adjusted, variations in current produced by varying the field might be as much as several hundred per cent. The results obtained fit in with the presence of two effects of the longitudinal field—increase of current by increase of ionisation by collision owing to the helical motion of such ions as initially have a component perpendicular to the electric force, and limitation (or decrease) of current by the effect that the ions executing such motion may spiral out of the path between the electrodes and be dispersed to the sides of the tube (*cf.* Hull, *Phys. Rev.*, July, 1921). It was soon found that the variation of current by the field depended on at least 3 variables—(1) distance between electrodes, (2) pressure of gas, and (3) magnitude of the current under stress. It is suggested that a failure to realise (3) may be responsible for lack of agreement reported by different observers. Not only does the curve of the percentage current change/field slope up more steeply for the smaller currents, but the saturation point (where further increase of field adds little to the change) occurs only at much higher values of field. The unidirectional component in a point-

to-plane discharge was affected by the magnetic field "in much the same way as the sinusoidal current." Tests with a transverse field confirmed that the usual current diminution (as utilised in the magnetic blowout for arc discharges) took place for $d=50$ mm. about, or for pressures exceeding a few mm.; but for small gaps, with pressure properly adjusted (*e.g.* 1.8 mm.), fields of a few hundred gauss may considerably increase the current, while larger fields may reduce it. There is a critical region of pressure and distance where the form of the graphs alters: in some experiments with hydrogen, it was found that a magnetic control could be effected where small transverse fields would decrease the current quite uniformly to 50 or 60 per cent. of the original value, while larger fields restored and even increased the current by more than 100 per cent. Still further increase of field reduced the current to extinction. Such a critical region was given by $d=4.6$ mm., $P=1.15$ mm., $i=3$ mA.

OSCILLATIONS IN IONIZED GASES.—Lewi Tonks and I. Langmuir. (*Phys. Review*, February, 1929, V. 33, pp. 195–210.)

Authors' abstract: A simple theory of electronic and ionic oscillations in an ionized gas has been developed. The *electronic* oscillations are so rapid (ca. 10^9 cycles) that the heavier positive ions are unaffected. They have a natural frequency $\nu_e = (ne^2/\pi m)^{\frac{1}{2}}$ and, except for secondary factors, do not transmit energy. The *ionic* oscillations are so slow that the electron density has its equilibrium value at all times. They vary in type according to their wavelength. The oscillations of shorter wavelength are similar to the electron vibrations, approaching the natural frequency $\nu_p = \nu_e(m_e/m_p)^{\frac{1}{2}}$ as upper limit. The oscillations of longer wavelength are similar to sound waves, the velocity approaching the value $v = (kT_e/m_p)^{\frac{1}{2}}$. The transition occurs roughly (*i.e.* to 5 per cent. of limiting values) within a 10-fold wavelength range centering around $2(2)^{\frac{1}{2}}\pi\lambda_D$, λ_D being the "Debye distance." While the theory offers no explanation of the cause of the observed oscillations, the frequency range of the most rapid oscillations, namely from 300–1,000 megacycles, agrees with that predicted for the oscillations of the ultimate electrons. Another observed frequency of 50–60 megacycles may correspond to oscillations of the beam electrons.

Frequencies from 1.5 megacycles down can be attributed to positive ion oscillations. The correlation between theory and observed oscillations is to be considered tentative until simpler experimental conditions can be attained.

DETECTION CHARACTERISTICS OF THREE-ELEMENT VACUUM TUBES.—F. E. Terman and T. M. Googin. (*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 149–160.)

Authors' summary: "The change of grid potential in a grid-leak grid-condenser detector can be determined by considering a fictitious 'rectified voltage' acting in series with the grid resistance. This equivalent voltage is inversely proportional to the tube 'voltage constant' v, which has the value $v = 2R\Big/\dfrac{dR_g}{dE_g}$, and can be readily measured by an A.C. resistance bridge.

"The rectifying action of different tubes can be compared on the basis of the respective voltage constants at grid resistances inversely proportional to the size of grid condenser. Tubes are then compared under conditions of equal detector distortion, and the change of grid potential is inversely proportional to the voltage constants.

"The voltage constant of ordinary vacuum tubes at first drops rapidly as the grid resistance is increased, but soon flattens out and becomes constant at grid resistances above 50,000 to 150,000 ohms.

"The highest audio-frequency that can be satisfactorily reproduced with the detector adjusted to full sensitivity is inversely proportional to the grid resistance at the lower end of the flat part of the v-R_g characteristic.

"It was found that tubes of the same type had uniform detection characteristics, that age, use, plate voltages between 16 and 122, and filament voltage (above the minimum necessary to give electron saturation) had little or no effect on the rectifying ability of high vacuum tubes at a given grid resistance in the useful range of operation."

The authors end by saying that although the results in this paper do not answer the question "exactly what design and construction features give a sensitive detector valve?" the data do indicate that the most important elements are *not* the voltage-drop in filament, type of filament (oxide or thoriated), power rating of valve, or changes in μ. It is hoped that definite conclusions can be reported ater.

DETECTION WITH THE FOUR-ELECTRODE TUBE: DISCUSSION.—(*Proc. Inst. Rad. Eng.*, January, 1929, V. 17, pp. 185–186.)

Discussion on Nelson's paper (Abstracts, 1928, V. 5, p. 521).

THORIUM- ODER ACID-RÖHREN? (Thorium or "Acid" Filaments for Valves?)—Telefunken Company. (*Rad. f. Alle*, January, 1929, pp. 16–17.)

Valves with the so-called "Acid" filaments have such increased emission and steepness (working as "dark-emitters") that in some ways it would be better to stop manufacturing thorium filaments altogether. Various reasons are given here, however, for the existence side by side of the two types.

OXIDE-COATED FILAMENTS AND SOME OF THEIR PROPERTIES.—A. M. Schemaew. (*Journ. Applied Phys.*, Moscow, No. 2, 1928, V. 5, pp. 35–49.)

In Russian, with German summary. A method is described by which a small platinum surface can be coated with a firm, smooth coating of oxide. Various phenomena are discussed—*e.g.*, a filament carefully out-gassed by prolonged heating in vacuo yields a great deal more gas when giving its emission current. The filament is activated by passing a large emission current. The activation is increased by the presence of mercury vapour at considerable pressure. One over-heating causes a complete loss of emission at low temperature, but this can be restored by the activating process.

An activated filament left cold in the presence of mercury vapour loses its activity after a time. A tungsten wire stretched near a heated oxide-coated filament acquires a strong emissivity for low temperatures.

VERY LOW VAPOUR PRESSURE GREASES AND OILS; THEIR PRODUCTION BY VACUUM DISTILLATION AND THEIR USE FOR JOINTS IN HIGH VACUUM SYSTEMS (10^{-6} MM.), FOR CONDENSATION PUMPS AND FOR LIQUID AIR TRAPS. (See *Proc. Roy. Soc.*, 6th March, 1929, V. 123 A., pp. 271–284: "Some Experiments on Vacuum Distillation," C. R. Burch.)

PHOTO-ELECTRIC EMISSION AND THERMIONIC EMISSION ONCE MORE.—E. H. Hall. (*Proc. Nat. Acad. Sci.*, February, 1929, V. 15, pp. 126–127.)

The writer argues that Du Bridge's experimental results (Abstracts, 1928, V. 5, p. 226) do not really imply that the amount of work required to overcome resisting forces is the same for an electron taken from the "free" state within a metal to the free state outside it, as for an electron taken by photoelectric action out of the metal. As for the so-called "universal constant" *A*, a 1927 paper of his predicted that it would prove different in different metals.

THE TEMPERATURE DEPENDENCE OF ELECTRON EMISSION UNDER HIGH FIELDS.—W. V. Houston. (*Phys. Review*, March, 1929, V. 33, pp. 361–363.)

Author's abstract: An expression . . . is secured by combining the results of Fowler and Nordheim with the Fermi distribution of velocities used in the Sommerfeld electron theory of metals. The result is similar to that obtained previously by considering the diminution of the work function by the field. The temperature variation is small and decreases as the external field increases. It is of the right order of magnitude to agree with the most recent observations.

PAPERS ON THE EMISSION OF IONS FROM CERTAIN SALTS (Halogen Derivatives of Lead, etc.).—J. Kahra and O. Birkenberg. (*Ann. der Phys.*, 2nd January, 1929, 5th Series, V. 1, No. 1, pp. 135–156 and 157–168.)

ÜBER DIE IONISATION DURCH ELEKTRONEN IN EINEM HOMOGENEN ELEKTRISCHEN FELDE (Ionisation by Electrons in a Homogeneous Electric Field).—M. J. Druyvesteyn. (*Zeitschr. f. Phys.*, 22nd November, 1928, V. 52, No. 3/4, pp. 197–202.)

The probability of ionisation in an inert gas is worked out by a method different from that of Penning and considered more likely to be accurate.

ARCS WITH SMALL CATHODE CURRENT DENSITY.—J. Slepian and E. J. Haverstick. (*Phys. Review*, January, 1929, V. 33, pp. 52–54.)

To account for the electric arc with cold cathode, Langmuir has proposed that electrons are drawn from the cathode by a very intense electrostatic field at the cathode surface, this field being set up by the positive space charge sheath which forms next the cathode. The writer shows that a consequence of this view would be that cold cathode arcs should not be able to exist with less than a minimum cathode current density of considerable magnitude; whereas he has found experimentally that at gas pressures of 10–50 mm., arcs with cathode current densities of less than 100 A. per cm.^{2} can exist.

ON THE MECHANISM OF ELECTRON OSCILLATIONS IN A TRIODE.—H. E. Hollmann. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 229–251.)

An abridged translation of the German paper referred to in Abstracts, 1928, V. 5, p. 582.

ON THE CHEMICAL INTERACTION OF IONS AND THE "CLEAN UP" OF GASES AT GLASS SURFACES UNDER THE INFLUENCE OF THE ELECTRICAL DISCHARGE.—J. Taylor. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A, pp. 252–270.)

CALCULATIONS ON VACUUM TUBES AND THE DESIGN OF TRIODES.—Y. Kusunose. (*Researches of the Electrot. Lab.*, Tokio, No. 237, September, 1928, 163 pp.)

ÜBER DIE BEFREIUNG DES ELEKTRONS AUS DER METALLOBERFLÄCHE DURCH LANGSAME POSITIVE IONEN (The Setting Free of an Electron from the Surface of a Metal by Slow Positive Ions).—O. Klemperer. (*Zeitschr. f. Phys.* 31st December, 1928, V. 52, No. 9/10, pp. 650–653.)

The probability of an electron being set free is worked out by two fundamentally different ways—from the known current-voltage measurements of the Townsend discharge and from the minimum spark potential and ionisation-expenditure of the electron in gas.

DIRECTIONAL WIRELESS.

FLUGZEUGSTEUERUNG BEI UNSICHTIGEM WETTER (The Piloting of Aircraft in Fog, etc.).—O. Scheller. (*E.T.Z.*, 7th February, 1929, pp. 191–192.)

The author patented, in 1907, the equi-signal beacon system recently re-developed for aircraft in the U.S.A. His system was tested (for ships) before the war, and for aeroplanes in 1917/1918.

ACOUSTICS AND AUDIO-FREQUENCIES.

THE EFFECT OF A FINITE BAFFLE ON THE EMISSION OF SOUND BY A DOUBLE SOURCE.—M. J. O. Strutt. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 537–548.)

From physical reasoning it may be expected that enlargement of the baffle beyond a certain critical point (the wavelength being given) will have only little effect; from phase considerations, this point may be expected to be about where the shortest air-path between front and back of the loudspeaker equals one half of the wavelength. In this paper,

the effect of a finite baffle on the sound emitted by an oscillating circular plate, of dimensions small with respect to the wavelength, is calculated by supposing two simple sources of equal amplitude and opposite phase to be placed at two diametral points of a sphere; the effect of increasing the diameter of this sphere on the circulation of air from one source to the other is taken to be essentially the same as the effect of increasing that of a flat baffle of finite dimensions.

The critical size of the baffle, predicted above, is confirmed by this investigation at the predicted value. Also, the effect of the baffle on the directive properties of the emitter is shown.

Über Strahlungs- und Richtwirkungseigenschaften von Schallstrahlern (Radiating and Directional Properties of Sound Emitters).—H. Backhaus. (*Zeitschr. f. tech. Phys.*, December, 1928, pp. 491–495.)

Theory of the energy-radiation from a spherical radiator; application to bowed instruments; method of determining the vibration-form of violins and similar instruments; directional effects with violins.

On the Condenser-Telephone.—G. Green. (*Phil. Mag.*, January, 1929, V. 7, No. 41, pp. 115–125.)

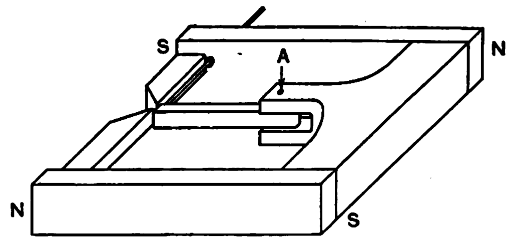
A former paper (*ibid.*, September 1926) gave a preliminary discussion of the mathematical theory of a two-plate telephone, one fixed and the other free to move. The present paper deals with a condenser consisting of a pile of plates, of which only the undermost is regarded as fixed. It explains the fundamental dynamical theory and indicates clearly the nature of the response curve and the conditions which determine the shape of the curve in any actual case. But in neglecting all second-order terms the investigation has been restricted to the case where the e.m.f.'s impressed on the condenser are very small compared with the constant e.m.f. applied to its plates, whereas in some of the more important applications so far made of the condenser-telephone this condition is far from being fulfilled.

Acoustic Considerations Involved in Steady State Loud Speaker Measurements.—L. G. Bostwick. (*Bell Tech. Journ.*, January 1929, V. 8, pp. 135–158.)

Author's synopsis: Certain difficulties encountered in acoustic measurements of the performance of loud speakers are described. Because of the nature of these difficulties it has not yet been possible to specify a complete and simple set of measurements or conditions which will completely express the performance of a loud speaker. Data are given showing the performance of two representative types of loud speaker both when measured in outdoor space free from reflections and when measured under varying conditions in a specially treated acoustic laboratory. The differences serve to emphasise the importance of certain precautions in the making of indoor acoustic measurements.

Die Bisher Üblichen Elektromagnetischen Lautsprecher-Systeme und das Neue Spannungsfreie Systeme (The Ordinary Electromagnetic Loud-speaker Systems, and the New Tension-free System).—F. Gabriel. (*Rad. f. Alle*, January, 1929, pp. 18–22.)

After describing how the older biased electromagnetic movements led to reproduction of bad quality, the writer illustrates an example of the more modern bias-free movement and shows how, in actual practice, it is impossible to adjust this so as to obtain real freedom from bias. He then



describes his own patent, which is not only free from bias, but also free from any spring tension—it is truly electromagnetically controlled. The illustration explains the construction; the pivot at *A* is jewelled; the rectilinear construction of the magnet system allows the highest quality of steel to be used. Tests are said to show great naturalness of reproduction.

A Microphone with Uniform Response (Igranic).—(*Engineer*, 18th January, 1929, V. 147, pp. 68–69.)

In an article on the Physical and Optical Societies' Exhibition, a microphone is described which is said to respond uniformly to "sound waves of all audible frequencies," with complete freedom from background noises. Several compartments are interspaced between the electrodes, each containing carbon granules of a size different from those in the other compartments. The diaphragm is non-conducting and non-resonant, and the "sound waves impinge on the diaphragm at right angles to the direction of current flow."

Apparatus for Generating and Measuring Sound, for the Study of Architectural Acoustics.—D. M. Crawford. (*Science*, 31st August, 1928, V. 68, pp. 209–211.)

The apparatus is said to give a constant pitch of tuning-fork accuracy over a wide range of intensities and for long periods of time, and can be made portable.

Transmission of Sonic and Ultrasonic Waves through Partitions.—R. W. Boyle. (*Nature*, 14th January, 1928, V. 121, pp. 55–56), and Passage of Acoustic Waves through Materials.—R. W. Boyle and J. F. Lehmann. (*Trans. Roy. Soc. Canada*, No. 1, 1927, V. 21, pp. 115–125.)

Ultrasonic tests showed that at (metal) plate

thicknesses of an odd number of quarter wavelengths, reflection was maximum and transmission minimum, while at thicknesses of a small integral number of half wavelengths the reverse was the case and nearly all the incident energy got through. Thus with a frequency of 300,000 p.p.s., a 2 mm. plate of type-metal could block off the beam completely, while a plate 2 or 4 or 6 times this thickness allowed the larger part of the energy to emerge through it. This agrees with Rayleigh's mathematical treatment of longitudinal waves, which led to the equation which may be expressed verbally in the words "when the *mass of a wavelength* in incident and reflecting media is the same, reflection is nil and transmission is perfect."

DU CHOIX D'UN CORNET ACOUSTIQUE (The Choice of an Ear Trumpet).—— Marage. (*Comptes Rendus*, 4th February, 1929, V. 188, pp. 466–468.)

The writer gives four curves each representing the loss of acuteness of hearing for the five vowel sounds, and each corresponding to a definite type of deafness. The shape of the curves remains fixed though their position on the loss-of-hearing scale may vary; two curves belong to the class due to injury to the middle ear, the other two to defects in the internal ear and auditory centres. He shows that the aid to hearing should be designed to suit the curve of the particular subject.

DIE TONERZEUGUNG DURCH SPITZEN AN HOHEM WECHSELPOTENTIAL UND IHRE VERWENDUNG ALS MEMBRANLOSER LAUTSPRECHER (Sound Production by Points at High A.C. Potential, and their Use as Membraneless Loud Speakers).—L. Fleischmann. (*Naturwiss.*, No. 42, 1928, V. 16, pp. 795–796.)

The A.E.G. have patented a loud speaker in which the sound is produced by A.C. voltage fluctuations at a metallic point, a suitable D.C. polarising potential being superimposed. Pureness of tone depends on the field strength and becomes bad when this is high enough to produce a glow discharge. The sound is due to the point action, and *not* to electrostatic forces.

THE ACOUSTIMETER.—R. F. Norris. (*Rad. Engineering*, February, 1929, V. 9, pp. 36–37.)

Description of a sound-intensity measuring apparatus, including a vacuum thermopile and millivoltmeter, used in the design of sound-proof partitions, investigation of auditorium acoustics, etc. "In each of these investigations, very slight differences of sound intensity were found to be the deciding factors in the direction of the research and in the final solution of the problems."

RADIO-GRAMOPHONES (Commercial Equipment reviewed): GRAMOPHONE PICK-UPS (19 Commercial Types discussed, with Table of Relative Outputs at different frequencies): FITTING A PICK-UP. (*Wireless World*, 6th March, 1929, V. 24.)

THE CONDENSER MICROPHONE DEVELOPED BY THE RADIO LABORATORY, NICHNY NOVGOROD.—S. I. Shaposhnikov. (*Teleg. i Telef. b. Prov.*, Nichny Novgorod, October, 1928, V. 10, pp. 536–539.)

EXPERIMENTS WITH HIGH FREQUENCY SOUND WAVES.—F. L. Hopwood. (*Journ. Scient. Instr.*, February, 1929, V. 6, pp. 34–40.)

A discourse given at the recent Exhibition of the Physical and Optical Societies. Various properties of the ultra-sonic waves are described and illustrated. Their application to the study of architectural acoustics is illustrated by a photograph showing how a beam of sound directed tangentially along the circular wall of a model "whispering gallery" tends to hug the wall, in accordance with Rayleigh's theory. Biological effects are described—the effect on the potency of the ultra-microscopic virus of Vaccinia, the arrest or retardation of beating of the embryonic heart of a chick, an increase in the agglutinating power of certain streptococci, the breaking up of the red blood corpuscle, the killing of tadpoles, etc., etc. Many of the results were also obtained independently by Wood and Loomis in America. *Cf.* Abstracts, 1928, V. 5, pp. 409 (Langevin) and 591 (Boyle).

THE MEASUREMENT OF SOUND ABSORPTION COEFFICIENTS.—P. E. Sabine. (*Journ. Franklin Inst.*, March, 1929, V. 207, pp. 341–368.)

A description of the methods used at the Riverbank laboratories. A table of coefficients is included, dealing with thirty-eight different materials or variations of the same material.

DYNAMIC SPEAKER HUM ELIMINATION.—P. G. Andres. (*Rad. Engineering*, February, 1929, V. 9, pp. 37–38.)

Copper spool head: "bucking" coil in series with moving coil: condensers across field winding—when used with dry-disc rectifier, shorten the life of this: electrical counteraction by adjustable resistance, the A.C. voltage drop across this being fed in opposite phase relation into the moving coil circuit—this has the advantage that it can often balance out, also, any hum introduced by the amplifier.

DER SELBSTTÖNENDE KRISTALL UND DAS MEMBRANLOSE (KRISTALL-) TELEPHON (The Singing Crystal and the Membraneless-Crystal — Telephone). — A. Ensbrunner. (*T.F.T.*, September, 1928, pp. 285–287.)

An account of Seidl's experiments with Lossew's crystal adaptation of the singing arc circuit discovered by Duddell. Methods of using the crystal as loud speaker, microphone and telephone are shown.

ÜBER DIE FREQUENZABHÄNGIGKEIT VON VERSTÄRKERTRANSFORMATOREN (The Frequency Dependence of Amplifier Transformers).—K. Matthies and G. Ganswindt. (*Arch. f. Elektrot.*, 15th February, 1929, V. 21, pp. 477–487.)

An experimental investigation, in the Telefunken

laboratories, of transformers for broadcast receivers. The test frequency range was from 50 to 15,000 p.p.s.

The Analysis of Irregular Motions, with Applications to the Energy-frequency Spectrum of Static and of Telegraph Signals.—G. W. Kenrick. (*See under* "Atmospherics.")

Verification of Ohm's Acoustic Law regarding Non-perception of Phase Changes. (*See* van der Pol, under Properties of Circuits.)

PHOTOTELEGRAPHY AND TELEVISION.

Television and the Problems Involved.—T. Thorne Baker. (*Photogr. Journ.*, June, 1928, V. 68, pp. 267–272.)

The difficulties in the way of the production of good quality images, by any of the present television processes, are considered.

Über die elektrolytische Herstellung von Photozellen und deren Verwendung (The Electrolytic Manufacture of Photoelectric Cells, and its Application).—L. Márton and E. Rostás. (*Zeitschr. f. tech. Phys.*, February, 1929, pp. 52–57.)

Sodium photoelectric cells can be turned out in quantity by the authors' simple process, using bulbs of lead-free soda-glass. No silvering process is needed, for after evacuation, sealing, and socketing, the layer of sodium is deposited on the inside surface by electrolysis of the glass, condensation into a continuous layer in the right position being ensured by air-cooling the right part of the bulb. A uniform matt coat is usually formed, but this is sometimes marred by well-defined mirror-like spots whose origin is still uncertain. The long wave limit of these cells is about 5,500 A.U.; for white light the average sensitivity is 3×10^{-10} A.U. per metre-candle. This is enough for photometric purposes, for which these cells should find a ready application; but it is far below the sensitivity of the carefully prepared potassium hydride cells used in phototelegraphy, etc.

Unfortunately, attempts to use potash glass and thus to make a corresponding potassium cell encountered unexpected difficulties which have not yet been overcome. The potash glass would apparently have to contain less than 0.1 per cent. of sodium—a condition technically difficult to satisfy.

The paper ends with a description of the application of these cells to photometric purposes, two amplifying arrangements being shown; one is electrically, the other photoelectrically, compensated against circuit variations.

Television.—(*Wireless World*, 13th March, 1929, V. 24, p. 273.)

A leading article based on a recent demonstration of the Baird system in London.

"Since the image is viewed through a magnifying lens and the internal mechanism was not disclosed to us, it is somewhat difficult to define the impression of the size of the image, but it would perhaps be safe to say that the image of the head and shoulders of a subject appeared as slightly under the size of a passport photograph, and the image was clear enough for the face to be recognisable on meeting the subjects of the transmissions face to face after the demonstration, though, in a witness box, one would probably decline to give evidence of identification." The picture transmission was on 200 m., and 2LO (358 m.) was tuned in without interfering.

"There is no doubt that the demonstration was a marked improvement, as far as steadiness of the picture and consequent *appearance* of sharpness and greater detail, over the demonstration which we witnessed at Olympia during the Radio Show last autumn."

Der gegenwärtige Stand der Bildtelegraphie: die neueste Entwicklungsstufe des Kornschen Verfahrens (The Present Position of Picture Telegraphy: the latest Development of the Korn System).—F. Noack. (*Rad. f. Alle*, February, 1929, pp. 88–91.)

Details, with schematic diagrams and photographs, of the latest form of the apparatus; together with two excellent black-and-white examples of the product.

Zur Theorie der lichtelektrischen Wirkung (On the Theory of the Photoelectric Effect).—H. Th. Wolff. (*Zeitschr. f. Phys.*, 22nd November, 1928, V. 52, No. 3/4, pp. 158–160.)

A hypothesis is put forward that in the photoelectric process, conduction electrons are emitted from the metal, energy being supplied to them (by collisions of the second kind) from optically excited atoms.

Das lichtelektrische Verhalten des Quecksilbers beim Übergang vom flüssigen in den festen Aggregatzustand (The Photoelectric Behaviour of Mercury on its Change from Fluid to Solid Aggregate State).—M. Grützmann. (*Ann. der Phys.*, 2nd January, 1929, 5th Series, V. 1, No. 1, pp. 49–73.)

A contribution to the problem of the mechanism of photoelectric action. As a result, it is found that the total photoelectric emission remains constant through the melting point, in contrast to electrical behaviour in other ways. At the melting point there is an electric effect independent of light, probably to do with the formation of vapour.

MEASUREMENTS AND STANDARDS.

A Vacuum-Tube Circuit for Measuring Small Alternating Currents.—R. E. Martin. (*Journ. Opt. Soc. Am.*, January, 1929, V. 18, pp. 58–61.)

An arrangement of four three-electrode valves and a D'Arsonval galvanometer, which will measure A.C. currents of the order of 10^{-9} A.—accurately at low frequencies, and with only small percentage

errors at high frequencies after the proper corrections are made, even though the calibration is carried out at low frequencies and for relatively high currents. The four valves, in two pairs, are so arranged that for each direction of the E.M.F. in the external circuit the current will pass through the galvanometer in the same direction.

During each half-cycle, one valve of each pair acts as a condenser and a resistance in parallel, while the other of each pair acts only as a condenser.

EINE KOMPENSATIONSMETHODE ZUR MESSUNG SCHWACHER STRÖME (A Compensation Method for the Measurement of Small Currents).—R. Jaeger. (*Zeitschr. f. Phys.*, 31st December, 1928, V. 52, No. 9/10, pp. 627–636.)

A "current standard," variable from zero to about 5×10^{-10}A., is here described which is useful for many types of small-current measurement (particularly by the constant deflection method). The principle involved is the use of the saturation current from a system of surfaces covered with uranium oxide, a screen with calibrated adjustment controlling the area of active surface. Examples of its use are described and illustrated.

KAPAZITÄTSVARIATOREN FÜR PRÄZISIONSMESSUNGEN (Variable Condensers for Precision Measurements). (*E.T.Z.*, 28th February, 1929, p. 319.)

Description of a German series of condensers specially designed for great accuracy. Quartz glass insulation is used. In one small-capacity condenser, the distance between plates can be adjusted by a micrometer spindle-adjustment—so that when so required the capacity change for one scale division can be reduced to 0.001$\mu\mu$F. In another, the patented construction leads to "an initial capacity which is truly zero."

ERMITTLUNG DER ENTLADEKURVE VON KONDENSATOREN (Plotting the Discharge Curves of Condensers).—H. Rühlemann. (*E.T.Z.*, 14th February, 1929, pp. 230–231.)

The use of a glow-discharge tube enables the discharge characteristic of a condenser to be obtained with very simple apparatus. The method is described and examples given.

ÜBER KAPAZITÄTSMESSUNGEN MITTELS PIEZOELEKTRISCHER OSZILLATOREN UND RESONATOREN (The Measurement of Capacity by the Use of Piezoelectric Oscillators and Resonators). —G. A. Kjandsky. (*Zeitschr. f. Phys.*, 31st December, 1928, V. 52, No. 9/10, pp. 743–745.)

After describing how a piezoelectrically stabilised oscillator can be used, by the zero beat-note method, to measure the capacity of an unknown condenser in a second circuit, the writer shows how the luminous quartz resonator of Giebe and Scheibe can be employed for such measurements: this method (the principle of which is obvious) is simpler than the former one and is very accurate. Its use need not, of course, be limited to capacity measurements.

BEITRAG ZUR MESSUNG DER SPANNUNGSVERTEILUNG AUF ISOLATOROBERFLACHEN (Contribution to the Measurement of Voltage-distribution on the Surface of Insulators).—P. Pulides and A. L. Müller. (*E.T.Z.*, 8th November, 1928, pp. 1648–1650.)

An improved method, applicable to insulators of all shapes, is described; it employs an amplifier and loud speaker.

EIN BELLATI-DYNAMOMETER SEHR HOHER EMPFINDLICHKEIT (A Bellati Dynamometer of Very Great Sensitivity).—A. Pfeiffer. (*Résumé* in *E.T.Z.*, 25th October, 1928, p. 1582.)

The writer has increased the sensitivity of this instrument (which measures A.C. as well as D.C.) sixty-three times by various improvements, to a value of 1.8×10^{-8}A.

ON THE MEASUREMENT AT RADIO FREQUENCY OF THE CONDUCTIVITY OF LIQUIDS WITHOUT IMMERSED ELECTRODES.—W. F. Powers and M. F. Dull. (*Journ. Opt. Soc. Am.*, October, 1928, Part I, V. 17, pp. 323–325.)

Burton and Pitt measure conductivity by means of an oscillating valve circuit. The authors use a non-generating circuit for the sake of the simpler theoretical treatment, employing a circuit described by Gunn for the measurement of very small capacity changes (*Phil. Mag.*, July, 1924). The paper is only a preliminary report on the method, giving some idea of its sensitivity. Change of strength of a salt solution from 0.025 per cent. to 0.038 per cent. produced a change of galvanometer deflection of about 8 cm. on the scale.

THE MEASUREMENT OF CONDUCTIVITIES BY MEANS OF OSCILLATING CIRCUITS.—S. D. Gehman and B. B. Weatherby. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 567–569.)

The writers believe Burton and Pitt's results (see above) to depend not on the conductivities but on the dielectric constants of the liquids concerned, and quote experiments to prove their point: in one of these, liquids were chosen whose conductivities were in the reverse order of their dielectric constants, and the Burton-Pitt deflections were found to be in the order of the latter, not of the conductivities.

ÜBER DIE VERWENDBARKEIT DER RESONANZMETHODE ZUR MESSUNG VON DIELEKTRIZITÄTSKONSTANTEN LEITENDER FLUSSIGKEITEN (The Applicability of the Resonance Method to the Measurement of the Dielectric Constants of Conducting Fluids).—H. Kniepkamp. (*Zeitschr. f. Phys.*, No. 1/2, V. 51, 1928, pp. 95–107.)

Results, using a 530 m. wave, showed satisfactory agreement with the values found by other workers by other methods. Resonance was judged by a potential-measuring indicator; a current-measuring indicator gave direct values which were always too small.

A CONVENIENT METHOD FOR REFERRING SECONDARY FREQUENCY STANDARDS TO A STANDARD TIME INTERVAL.—L. M. Hull and J. K. Clapp. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 252–271.)

A method is described for obtaining a convenient low frequency from a high frequency standard by means of "harmonic control of distorted wave oscillators," *i.e.*, by injecting into an Abraham multivibrator a frequency which is an integral multiple of the multivibrator fundamental, thus making the multivibrator into a step-down frequency transformer.

A 50 kc. piezo oscillator, temperature-controlled by a bi-metallic thermostat, feeds into a 10 kc. multivibrator through an isolating amplifier. (This multivibrator circuit has a coupling coil which is used to provide a series of harmonics on the 10 kc. fundamental, for calibrating purposes.) Next comes a second isolating amplifier and a 1 kc. multivibrator, followed by a 1 kc. amplifier and by a synchronous motor with clock train, designed to keep time when the frequency supplied is 1,000 cycles p.s.—so that the timing of the H.F. source is reduced to observations of small time errors indicated by the clock.

Assuming that the momentary deviations from the 24-hour mean are not greater than the maximum fluctuations observed in a long interval (10 days), the variations worked out at about 8 parts per million. This result was improved by the building of a "new temperature control box . . . though use was still made of the bi-metallic thermo-regulator." The variation was thus reduced to about 2 per million. Lines of further development are (1) provision of temperature control within one or two hundredths of a degree; (2) replacement of present quartz-bar holder insulation by a vitreous material showing negligible distortion with age at constant temperature; and (3) improvements in the clock mechanism and in methods of checking against the time signals.

A large middle section of the paper deals with a systematic experimental investigation of the behaviour of the Abraham multivibrator when thus harmonically controlled, leading to the conclusion that the appropriate multivibrator harmonic bears a constant and permanent phase relation to the injected "control" oscillation; and that the frequency of this harmonic, and therefore of the fundamental, follows any drift or perturbation in the frequency of the control oscillation without appreciably altering the phase relation or dropping out of synchronism even for a single cycle. The use of a neon tube relaxation oscillator, as a substitute for the dissymmetrical valve oscillator, is therefore abandoned as inferior.

A 50/1 step-down is considered the suitable limit—hence two compounded multivibrators would have been used even if the 10 kc. stage had not been needed for harmonic calibration purposes.

The quartz oscillator circuit selected was one of the class in which sustained oscillations are impossible without the quartz bar: experience had indicated that the frequency is more precisely determined by the mechanical vibration of the quartz if no other periodic element is present which can support sustained oscillations independent of the mechanical vibrator.

LA MESURE DES TRÈS HAUTES FRÉQUENCES RADIOTÉLÉGRAPHIQUES AU MOYEN DES OSCILLATEURS À QUARTZ PIÉZO-ÉLECTRIQUE (The Measurement of Very High Frequencies by Means of Piezoelectric Quartz Oscillators). —B. Decaux. (*Comptes Rendus*, 11th February, 1929, V. 188, pp. 498–499.)

Oscillators in general use have fundamental frequencies of the order of 10^6. Using a tuning fork with a fundamental of about 1,024, the writer obtains a series of frequencies differing by 1,024 up to 10^8, by the following method:—the H.F. oscillator (frequency F) is coupled to one of the grid circuits of a two-grid valve whose plate circuit contains the oscillating circuit coupled to the indicating instruments. The second grid circuit receives a L.F. potential (frequency f) from the tuning-fork circuit. Currents of frequencies $F \pm f$, $F \pm 2f$, etc., appear in the plate circuit. By repeating the process with the various harmonics of F, a whole series is obtained. (*Cf.* the same writer, April Abstracts.)

A SYSTEM FOR FREQUENCY MEASUREMENTS BASED ON A SINGLE FREQUENCY.—E. L. Hall. (*Proc. Inst. Rad. Eng.*, February, 1929, V. 17, pp. 272–282.)

A method for calibrating piezo-oscillators or frequency meters, in terms of an accurately known fixed frequency standard—the result *not* depending (as in usual methods) on the calibration of a (H.F.) frequency meter as an intermediate step in the measurement. The method depends on the audio-frequency measurement of the beat note between the apparatus under test and a local generator oscillating at a harmonic of the fixed standard.

EIN GERÄT ZUR MESSUNG VON MAXIMALSPANNUNGEN IN FERNSPRECHÜBERTRAGUNGSSYSTEMEN (An Apparatus for the Measurement of Maximum Peak Voltages in Telephone Transmission Systems.)—D. Thierbach. (*Zeitschr. f. tech. Phys.*, November, 1928, pp. 438–442.)

Describes a direct-indicating "impulse meter" designed to watch over the transmission so that over-control may be avoided. Previous apparatus only indicated whether the incoming voltages were greater or less than the grid bias of the indicator valve. The actual measurement of the maximum peaks is complicated by the short duration of some of these. The method adopted is the audion circuit with condenser in the grid circuit, the indication being given by a meter in the plate circuit. The charging-up time of the condenser is very small (the curve becoming almost horizontal after 1/50 sec.): it is periodically (once in 2–10 secs.) discharged either by hand or by a relay so as to be ready for a new measurement. *Cf.* Mayer, March Abstracts, p. 166. Full details are given, together with examples of the uses of the apparatus.

MESSUNGEN AN NIEDERFREQUENZVERSTÄRKERN (Measurements on L.F. Amplifiers).—R. Wigand. (*Rad. f. Alle*, February, 1929, pp. 64–70.)

The article includes diagrams of various methods (including the Telefunken and the author's own

method) of obtaining L.F. pure sine-wave oscillations.

DETERMINING THE DISTRIBUTION OF ELECTRIC AND MAGNETIC FIELDS.—B. Hague. (*Electrician*, 15th March, 1929, V. 102, pp. 315–317.)

Second and final part of the paper referred to in April Abstracts. The methods described include the thermal analogy method, the isotherms being indicated by lines of demarcation in a mixture of wax and elaidic acid; the electrochemical and hydrodynamical (Hele-Shaw) methods and (probably the most generally useful) the electric conduction method (especially in the modified form using an electrolyte tank—capable of attacking three-dimensional problems) and the soap-film method. A very extensive index to the literature is given.

ZUR BERECHNUNG VON EISENLOSEN DROSSELSPULEN UND DER ZWISCHEN KOAXIALEN SPULEN WIRKENDEN KRÄFTE (The Calculation of Air Core Chokes and the Forces between Co-axial Coils).—J. Hak. (*E.T.Z.*, 7th February, 1929, pp. 193–198.)

Includes graphs giving the inductance of air-core circular coils with rectangular winding-section; and others giving the ratio weight of copper/inductance for various proportions of coil, mutual induction between co-axial coils (near and distant), and forces between co-axial coils.

DAS RÖHRENVOLTMETER ALS ANZEIGEINSTRUMENT FÜR OBERWELLEN (The Thermionic Voltmeter as an Indicating Instrument for Harmonics).—W. Deutschmann. (*T.F.T.*, January, 1929, pp. 24–26.)

Since its readings depend on relative amplitude, harmonic order and phase displacement, the thermionic voltmeter is unsuitable for the measurement of harmonics.

SUBSIDIARY APPARATUS AND MATERIALS.

ÜBER DIE DURCH KATHODENSTRAHLEN BEWIRKTE ELEKTRISCHE AUFLADUNG DES GLASES UND DEREN PRAKTISCHE VERWENDUNG (The Charge on Glass produced by Cathode Rays, and its Practical Utilisation).—P. Selényi. (*Zeitschr. f. tech. Phys.*, November, 1928, pp. 451–454.)

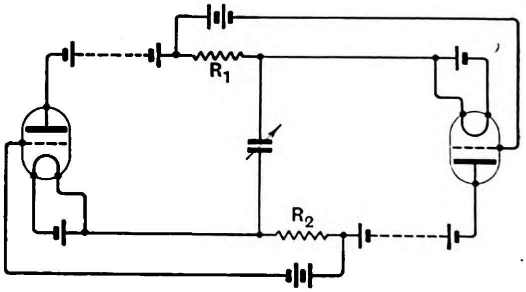
An extension of a previous paper (Abstracts, 1928, V. 5, p. 467) on the formation of cathode ray oscillograph figures by scattering powder (sulphur and red-lead) on the outside of the glass wall. Various improvements have been made, and a number of specimen records are given (including one of 500 frequency A.C.). A recording speed of 4,000 cm./sec. is obtained with a ray intensity of about 2μA.; it is argued that with a ray intensity of 1 mA. the speed should be raised to 10 km./sec., so that a H.F. oscillograph, electrostatically recording, would appear to be within reach. Improvements still to be desired, and difficulties, are mentioned: *e.g.*, the thickness of the glass wall causes a " fuzziness " in the record.

REGISTRIERENDES PRÄZISIONSGERÄT FÜR SEHR SCHWACHE STRÖME (Precision Recording Apparatus for Very Weak Currents).—C. Müller and R. Frisch. (*Zeitschr. f. tech. Phys.*, November, 1928, pp. 445–451.)

Designed primarily for recording values of light-intensities, ionisation processes, etc., the apparatus works with comparative rapidity and great freedom from interference—on currents of the order of 10^{-13}A., with a mean error of 1–2 in a thousand. It consists in a projecting thread-electrometer controlled by a photoelectric cell, the projection of the image of the thread on to a photographic drum being interrupted by a disc (carrying apertures arranged to suit the particular purpose) driven in intermittent rotation by clockwork. This clockwork also effects an intermittent earthing of the thread. Many records of performance are illustrated.

EINE NEUE SCHALTUNG ZUR ERZEUGUNG VON SCHWINGUNGEN MIT LINEAREM SPANNUNGSVERLAUF (A New Arrangement for the Production of Oscillations with Linear Voltage-Curve).—G. Frühauf. (*Arch. f. Elektrot.*, 15th February, 1929, V. 21, pp. 471–472.)

Oscillations of a triangular wave-form, useful for laboratory purposes (*e.g.*, for use with a Braun



tube), can be produced by this circuit using a pair of matched valves.

BESEITIGUNG DER NEBENFREQUENZEN BEIM STATISCHEN FREQUENZWANDLER (Suppression of Secondary Frequencies in Static Frequency Multipliers).—H. Freese. (*Zeitschr. f. Hochf. Tech.*, January, 1929, V. 33, pp. 1–8.)

This, the first of two parts, deals with the determination (first theoretical, then experimental) of these frequencies. The second part will deal with their suppression (see below).

BESEITIGUNG DER NEBENFREQUENZEN BEIM STATISCHEN FREQUENZWANDLER (Suppression of Secondary Frequencies in Static Frequency Multipliers).—H. Freese. (*Zeitschr. f. Hochf. Tech.*, February, 1929, V. 33, pp. 41–46.)

This second and final part of the paper referred to above deals with the experimental investigation of two methods (due to Lorenz and Zenneck respectively) of suppressing the unwanted

oscillations without seriously weakening the working oscillation. The first consists in the use of two absorption circuits connected in parallel, each of which by itself is tuned to an harmonic next to the wanted frequency (*e.g.*, for 15-fold multiplication, one is tuned to the 13th, the other to the 17th, harmonic—since it was shown in the first part that only the odd harmonics of the primary frequency are formed) while in parallel they are tuned to form a rejector circuit for the working frequency (15th harmonic). The second method uses two circuits each tuned to the working frequency but coupled together so that the resultant coupling-frequencies correspond to the two neighbouring unwanted frequencies. The two methods are shown to be very similar in their working. There is a critical value for the coupling between absorption system and main system; below this value the system is practically ineffective, while above it the system suppresses the two particular frequencies but increases other more distant harmonics. This holds good for secondary or tertiary circuit cleaning. When using the absorption system in the secondary circuit of a 15-fold multiplier, small detunings of the secondary circuit were found to have no special effect; but when using it in a tertiary circuit loosely coupled to the secondary, it was better to tune this tertiary circuit to a slightly lower frequency.

THE ELECTRICAL CONDUCTIVITY OF THIN OIL FILMS. PART I.—GENERAL NATURE OF THE PHENOMENON.—H. E. Watson and A. S. Menon. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A., pp. 185–202.)

Vaseline and heavy paraffin oil are now widely used for application to plugs and sliding contacts on measuring instruments—an apparent anomaly in view of the fact that these substances are ordinarily regarded as excellent insulators. The paper describes a detailed examination of the region in which a transition from insulation to conduction appears to take place. Flooded films of paraffin oil will stand a high potential gradient (over 100,000 v./cm.) as long as their thickness is more than about 15μ. At 11μ there is a tendency to break down with a much smaller gradient, the breakdown thickness not varying greatly with the voltage. The film becomes conducting in two stages; in the second stage the resistance is very low. The paper includes a description of the methods for determining non-conducting film thicknesses by means of capacity measurements.

THE DIRECT CURRENT CONDUCTIVITY OF INSULATING OILS.—D. H. Black. (*Phil. Mag.*, No. 36, 1928, V. 6, pp. 369–384.)

The writer propounds a theory to explain the irreversible process of the gradual decrease, with time, of the current flowing between two electrodes in an insulating liquid when a constant P.D. is applied. The theory calls for a contact resistance, at one or both electrodes, produced by the passage of the current. Various results fit in with the theory.

TESTS ON VACUUM LIGHTNING ARRESTERS FOR COMMUNICATION LINES.—T. Nishi and M. Hoshiai. (*Journ. I.E.E., Japan*, October, 1928, pp. 1028–1064.)

DURCHSCHLAG VON FESTEN ISOLATOREN BEI HOCHFREQUENZ (The Breakdown of Solid Insulators by High Frequency).—L. Inge and A. Walther. (*Arch. f. Elektrot.*, 7th December, 1928, V. 21, pp. 209–227.)

Measurements on the dielectric strength of glass, mica, and porcelain, mostly at a frequency of 4.35×10^5, in air, transformer oil and xylol. A glow discharge at the electrodes lowered the breakdown voltage considerably: xylol, which weakens this discharge the most, gave the highest breakdown values. With glass and porcelain there is a very marked dependence on frequency and temperature—the breakdown voltage is about proportional to the square root of the frequency (actual range of wavelengths used was about 250 m. to 1,140 m.). Mica behaves very differently, the breakdown voltage being independent of the frequency and only very slightly dependent on the temperature: the mechanism of breakdown seems to be quite different—probably an ionisation effect, as at low frequencies; whereas with glass and porcelain it is a heat effect.

ELECTRICAL INSULATING MATERIALS FROM A CHEMICAL STANDPOINT.—W. H. Nuttall. (*Chem. and Industry*, 28th December, 1928, V. 47, pp. 1359–1368.)

The main object of this paper is to answer the question "Considering the insulating compounds in general use, can we discover among them any common chemical characteristic, the possession of which bestows insulating properties?" At the end the writer says: "It is thus evident that most organic compounds employed as electrical insulators are employed in a high state of polymerisation or degree of association. We have here, so it seems, the exact converse of a dilute electrolytic solution which conducts by virtue of the electrolyte dissociating into positive and negative ions. An insulator can only become conducting after the material of which it is composed has become ionised or dissociated, and it is reasonable to suppose that a highly associated molecule is more difficult to ionise than an unassociated one. In any case, so far as I am aware, matter in a high degree of association is always a bad conductor of electricity. In conclusion, I would add that the more immediate improvements in electrical insulating media are most likely to be in the direction of the employment of purer materials. A trace of an unsuitable constituent in an insulator can easily render it quite unsuitable for its purpose. Thus, it has recently been shown that by removing the protein matter from rubber latex by means of caustic alkali, the breakdown voltage of ebonite prepared therefrom can be raised by 300–400 per cent."

A TRANSFORMER FOR THE FILAMENT CURRENT OF HIGH TENSION RECTIFYING VALVES.—E. P. Hudson and P. M. S. Blackett. (*Journ. Sci. Inst.*, December, 1928, V. 5, pp. 391–392.)

Specification and photograph of a transformer for supplying filament current (3A. at 6V.) to a valve working on 40,000 v. Primary (600 turns) is wound on a stalloy ring 18 cm. diam.; secondary (20 turns bound together into a ring 21 cm. diam.)

interlaces primary at right angles and is nowhere nearer than 7 cm. from it.

Ferromagnetic Ferric Oxide.—E. F. Herroun and E. Wilson. (*Proc. Physical Soc.* 15th December, 1928, V. 41, Part 1, pp. 100–111.)

Carboloy—A New Tool Material.—S. L. Hoyt. (*Gen. Elec. Review,* November, 1928, V. 31, pp. 585–591.)

A tungsten carbide and cobalt combination which will scratch sapphire and will retain its hardness and cutting edge at a bright red heat. Tools made from it successfully turn grooves in glass: manganese steel becomes machinable.

Die Theorie des Telephonrelais (The Theory of the Telephone Relay).—W.Th.Bähler. (*E.T.Z.*, 6th and 13th December, 1928, pp. 1780–1784 and 1810–1814.)

An Unusual Way of Insulating a Heating Element.—(*Engineer*, 4th January, 1929, V. 147, p. 13.)

The Westinghouse Company wrap the element round with metallic magnesium ribbon and insert the whole into a copper tube. Steam at 450 lbs. pressure converts the magnesium into its oxide: the result is a tube containing a heater element embedded in a hard, dense insulating material.

The Theory of the Metal Rectifier: Some Notes on the Properties and Method of Using the Dry Metal Rectifiers.—Engineering Dept., Westinghouse Co. (*Wireless World*, 19th December, 1928, V. 23, pp. 824–826.)

The Duriron-Duralumin Electrolytic Rectifier.—N. E. Woldman. (*QST.*, October, 1928, V. 12, pp. 45, 80, 82, 84, 86 and 88.)

Anode is duralumin (copper-aluminium alloy specially heat-treated and aged) and cathode is duriron (non-machinable, brittle iron-silicon alloy which resists electrolytic corrosion): electrolyte contains diammonium hydrogen phosphate and (as depolariser) potassium dichromate and oxalic acid. Normal operating current is 40 mA., at an output voltage up to 180 v. Temperature never rises above 40 deg. C., giving long life: this cool working is largely due to the oxide film on the duralumin electrode being very thin.

L'Alimentation des Récepteurs radiotéléphoniques: État actuel, derniers Progrès (Power Supply for Radiotelephone Receivers: Present Position: Latest Progress).—L. G. Veyssière. (*T.S.F. Moderne*, September and October, 1928, V. 9, pp. 538–551 and 617–631.)

Anode and filament supply is dealt with. The conclusion is that at the moment one can supply a receiver completely from any mains supply, but that the apparatus required is fairly complicated and lacks flexibility.

The Everlite Lamp: a Battery Lamp Unit for which Efficiency and Economy are Claimed.—*Electrician*, 1st February, 1929, V. 102, p. 141.)

Schmid, the inventor of the Everlite battery, says that the fact that only from 5 to 10 per cent. of a dry cell is used up chemically led him to develop a battery which has a constant discharge curve and can be re-charged: the refills being made in non-hydroscopic capsules. Tests are described on a battery giving 3 A. for 6 hours at 1½ v.

Weitere Untersuchungen an den Hochohmwiderständen (Further Investigations on High Resistances).—A. Gyemant. (*Wiss. Veröff. a.d. Siemens-Konz.*, No. 1, 1928, V. 7, pp. 134–143.)

Deals with high resistance liquid resistances. The negative temperature coefficients of certain liquids can be nullified by the admixture of other substances. Up to about 4 kv./cm. the resistance remains constant, but decreases gradually with higher field-strengths.

STATIONS, DESIGN AND OPERATION.

Kalundborg Radio.—K. Christiansen. (*Elec. Communication*, July, 1928, V. 7, pp. 24–32.)

Description of the main Danish broadcasting station. The four-wire aerial, 145 m. long, is suspended from two 100 m. masts spaced 220 m. apart, so that there are considerable gaps between the down-leads and the masts. There is a down-lead at each end of the aerial, the one going to the transmitter, the other (through a tuning coil) to the earth system. When properly tuned, the currents in the two down-leads are equal; there is a current node at the mid-point of the aerial. More effective current distribution to the earth network, and consequently smaller earth losses, are claimed as advantages of this arrangement.

Ein Kurzwellensender für die Tschechoslowakei (A Short-Wave Transmitting Station for Czecho-Slovakia).—(*Rad. f. Alle*, February, 1929, p. 87.)

A Telefunken short-wave station at Podeprady, near Prague, is being constructed, to open "in the first half of 1929." It possesses two transmitters, each of 20 kw. valve-output, working on 15–30 m. wavelengths for communication with America.

Der Kurzwellensender "AFK" in Döberitz (The Short Wave Station "AFK" at Döberitz).—(*E.T.Z.*, 21st February, 1929, p. 268.)

Summary of a paper in *T.F.T.*, V. 17, p. 305, by G. Kette, describing the Telefunken 15–100 m. transmitter installed for the German P.O. for research work, etc., in telegraphy, telephony and picture transmission.

Die Funkstellen der Welt; ein neues Verzeichnis der Funkstellen (The Wireless Stations of the World: a new List).—(*E.T.Z.*, 7th February, 1929, pp. 202–203.)

An article on the 12th edition of the international

list published by the Berne International Bureau in English, French and German.

THE NEW BROADCAST AMPLIFIER PLANT IN THE BERLIN STATION (ILLUSTRATED).—K. Müller. (*T.F.T.*, December, 1928, pp. 366–370.)

GENERAL PHYSICAL ARTICLES.

EINSTEIN'S FIELD-THEORY.—A. S. Eddington. (*Nature*, 23rd February, 1929, V. 123, pp. 280–281.)

The writer gives a modified and shortened version of Einstein's recently published "Unified Field-Theory," and compares it with his own affine field theory (*Proc. Roy. Soc.*, 1921, V. 99, p. 104) which, though resting on the same equation, presents very marked contrasts. While pointing out that to say that Einstein's or Weyl's or Eddington's illustrative geometry is the only right one would be like saying that a graph of a moving particle with time and space as co-ordinates is right but a graph with velocity and curvature as co-ordinates is wrong, he confesses that he cannot readily give up the affine picture, where gravitational and electrical quantities supplement one another as belonging respectively to the symmetrical and anti-symmetrical features of world measurement. One point in the new theory he criticises, as raising hopes that the field laws are about to appear as identities, whereas these hopes are not fulfilled: "Can any theory which requires field laws other than identities give real satisfaction? To introduce a field law limiting the geometrical possibilities is a confession that the initial geometry was too wide."

UNIFIED FIELD THEORY OF ELECTRICITY AND GRAVITATION.—N. Wiener and M. S. Vallarta. (*Nature*, 2nd March, 1929, V. 123, p. 317.)

The writers urge the application of Einstein's recent work on distant parallelism to the harmonisation of the general relativity theory with the quantum theory, particularly with Dirac's theory of the spinning electron—"a much more pressing need" than the development of a unified field theory of electricity and gravitation.

AN UPPER LIMIT TO ENERGY DENSITY.—S. Suzuki. (*Nature*, 23rd February, 1929, V. 123, p. 296.)

Summary of a paper in a Japanese physico-mathematical "proceedings." Just as on the theory of relativity there is a limit to the velocity a body can have, so there should be a limit to the energy which can be concentrated in a given volume, and (since the energy density in an enclosure is proportional to the fourth power of the absolute temperature of the enclosure) an upper limit to temperature. Planck's radiation formula would require an additional term becoming important for long waves and high temperatures. The frequency of a light quantum could not increase indefinitely, and the Compton increased frequency effect could not be produced when an extremely rapid electron struck a quantum of extremely high frequency. *Cf.* Pokrowski, April Abstracts.

ANFANGSSPANNUNG UND GASDICHTE BEI VERSCHIEDENEN ELEKTRODENFORMEN (Sparking Voltage and Gas Density for Electrodes of various Shapes).—S. Franck. (*Arch. f. Elektrot.*, 17th December, 1928, V. 21, pp. 318–374.)

An exhaustive investigation which deals with the behaviour not only of a large number of different electrode shapes, of length of spark gap, of temperature and pressure, but also of moisture.

ELECTRIC FLASHES TRAVEL IN SPIRALS, AS SHOWN BY HIGH-SPEED CAMERA. (*Technique, Montreal*, November, 1928, V. 3, pp. 28–29.)

A Westinghouse engineer has designed a camera taking 2,600 photographs per second: with this he shows that the path pursued by an electric flash is a highly complex spiral.

A NEW HIGH POTENTIAL X-RAY TUBE.—C. C. Lauritsen and R. D. Bennett. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 850–857.)

Description of the attempt, at the California Institute of Technology, to generate and investigate X-rays in the region beyond 300 kv. The tube has been designed to work at 1,000,000 volts: so far 750 kv. have been successfully used without special out-gassing of the electrodes. Cold emission is utilised, the full potential being applied between suitably curved electrodes close together. Absorption measurements of the X-rays have been made with lead up to 2 cm. thick, and it is shown that secondary emission plays an important part in the photo-chemical action of these rays.

MEASUREMENTS ON THE ABSOLUTE INTENSITY OF X-RAYS.—T. E. Aurén. (Abstract in *Science Abstracts*, 25th December, 1928, V. 31, pp. 929–930.)

The method depended on the measurement of the heat excited in metals by absorption of the rays. One of the deductions is that the energy necessary to produce a pair of ions shows no increase with decreasing wavelength.

SECOND CONTRIBUTION TO THE STUDY OF THE LIGHT ETHER.—V. Posejpal. (*Bohemian Ac. Sc. and A.*, Class II, 19th October, 1928.)

Nature summarises thus:—"ultra-penetrating radiation, heat of the earth and sun, the source of Swanne's electrons keeping up the earth's negative charge, are accounted for by the hypothetical neutron constitution of the ether."

WEITERE MESSUNGEN DER DURCHDRINGENDEN HÖHENSTRAHLEN (Further Measurements of the Penetrating Radiation).—K. Wölcken. (*Vortragshandbuch, 90 Versamm. d. Ges. deut. Natur. forsch., Hamburg*, September, 1928.)

The summary gives the statement that the only things we know for certain about these "Hess radiations" are:—that they exist, that their mass-absorption coefficient μ/ρ is of the order of 2.0×10^{-3} cm^{-1}, that the source must be over 30 km. high, and that no such radiations are known on

earth. They are very probably ultra-short gamma rays. The measurements of Kolhörster, v. Salis and Buttner indicate a cosmic origin: the radiation shows a daily period, depending on stellar time. Those of Millikan, Hoffmann, Steinke and Clay contradict this. Further measurements by the writer (round Mont Blanc and Göttingen) confirm the daily period, but only by averaging over periods of at least one hour. A decrease of relative amplitude through screening by air, ice or lead was not established. Göttingen measurements indicated variations of shorter duration, which could not be explained by assuming the passage of the centre of radiation through the meridian.

COSMIC RADIATION AND RADIOACTIVE DISINTEGRATION.—L. R. Maxwell. (*Nature*, 29th December, 1928, V. 122, p. 997.)

The test of Perrin's theory (that the disintegration of radioactive elements may be due to their absorption of cosmic radiations) mentioned in Abstracts, 1928, V. 5, p. 469, has now been made, with a negative result: unless it is assumed that the radiation responsible for the disintegration is of such penetrating power that it remains practically unabsorbed in going about eleven hundred feet through the earth, and yet has the property of being appreciably absorbed by relatively small amounts of radioactive elements.

THE ELECTRICAL CONDUCTIVITY OF METALS.—R. Ruedy. (*Nature*, 8th December, 1928, V. 122, p. 882.)

"In the recent theories of metallic conduction the exchange of electrons between neighbouring atoms has perhaps not been sufficiently considered. . . . For distances of the order of those which separate the atoms in a crystal lattice, electrons go over from one atom to the other more than 10^{10} times per second." The frequency of interchange is a function of certain variables shown by Herzfeld to be decisive in making an element a metallic conductor. Certain values would result in super-conductivity. This sharing of electrons would account for the magnetic properties of single metal crystals of zinc and cadmium, recently investigated.

ON FREE AND BOUND ELECTRONS IN METALS.—R. Ruedy. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 974–978.)

Author's abstract: When the theory of dispersion in an absorbing medium is applied to the values published in recent years for the optical properties of different metals, it follows that bound electrons exist inside the metal comparable in number with that of the free electrons.

THE PHOSPHORESCENCE OF FUSED QUARTZ.—A. C. Bailey and J. W. Woodrow. (*Phil. Mag.*, December, 1928, V. 6, pp. 1104–1107.)

Many samples of fused quartz when excited by ultra-violet light will emit a visible phosphorescent light of considerable strength upon the application of heat: even without heating they will affect a photographic plate for at least 3 weeks after their irradiation. Natural quartz crystals do not possess this property, but they can be brought into this condition by heating slowly in an electric furnace to a temperature of 1,600 deg. C.

A THERMAL PROPERTY OF MATTER.—Q. Majorana. (*Nature*, 24th November, 1928, V. 122, p. 825.)

Summary of experiments described in the Proceedings of the Royal Academy, Bologna. "Certain substances, in particular lead and iron, are found to be capable of exhibiting, in relation to the surrounding medium, thermal super-elevations which depend on the previous treatment of the substance and are not in accord with the well-known laws of the progressive cooling of bodies." This phenomenon is regarded as due to a progressive emission of thermal energy by matter after being heated to any marked degree. *Cf.* Brush (tests on complex silicates, with reference to his "energy-shadow" theory of gravitation), Abstracts, 1928, p. 588.

AN ATTEMPT TO POLARISE ELECTRON WAVES BY REFLECTION.—C. J. Davisson and L. H, Germer. (*Nature*, 24th November, 1928. V. 122, p. 809.)

Describes an experiment to test whether or not electron waves are polarised by reflection from the face of a crystal. The method was similar to the double mirror experiment by which the polarisation of light by reflection from glass is demonstrated, and was such that any polarisation occurring would be indicated by a periodic variation of current with angle. Within the limits of accuracy of the experiment, no such variation was found; so that it would appear that there is no polarisation by reflection.

IMPOSSIBILITY OF POLARISING ELECTRONIC WAVES.—A. F. Joffé, A. N. Arsenieva, J. Frenkel. (*Comptes Rendus*, 7th January, 1929, V. 188, pp. 152–155.)

The first two writers give experimental proof; the last shows that theoretically there is no effect, for electronic waves, corresponding to the polarisation of light.

VERSUCH ÜBER DIE POLARISATIONSFÄHIGKEIT EINES ELEKTRONSTRAHLS (Experiments on the Polarizability of an Electron Beam).—F. Wolf. (*Zeitschr. f. Phys.*, 4th December, 1928, V. 52, No. 5/6, pp. 314–317.)

If electrons are magnetic dipoles, a beam of them passing through a magnetic field should show some effect of polarisation. The experiment described shows no such effect.

APPARENT EVIDENCE OF POLARISATION IN A BEAM OF BETA-RAYS.—R. T. Cox, C. G. McIlwraith and B. Kurrelmeyer. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 544–549.)

This preliminary report records an apparently definite asymmetry in double scattering, which can be qualitatively explained in terms of the properties of the spinning electron.

THE RAMAN EFFECT WITH LIQUID OXYGEN, NITROGEN, AND HYDROGEN. — J. C. McLennan and J. H. McLeod. (*Nature*, 2nd February, 1929, V. 123, p. 160.)

Results show: (1) that Raman effects can be obtained with homopolar molecules; (2) that part of the energy of light quanta can be taken up directly as rotational energy, the balances appearing as quanta degraded in frequency; (3) that two-quantum rotational transitions can be demonstrated in connection with light-scattering phenomena; (4) that Dennison is correct in his view that hydrogen at low temperatures must be regarded as a mixture of two effectively distinct sets of molecules, symmetrical and antisymmetrical.

WAVELENGTH SHIFTS IN SCATTERED LIGHT.— A. E. Ruark. (*Nature*, 1st September, 1928, V. 122, pp. 312–313.)

Although the writer believes that the Raman-Krishnan radiation is actually the scattered light of modified wavelength predicted by Kramers and Heisenberg, he points out that it has never yet been proved *not* to be a fluorescent emission following the absorption process after a finite interval. He suggests that the question could be settled by determining whether there is a time lag; the method of Abraham and Lemoine, using a Kerr cell as a very rapid electromagnetic shutter, has already been used to show a lag of 2×10^{-8} sec. for the phosphorescence of rhodamine.

LES RADIATIONS SECONDAIRES DANS LA LUMIÈRE DIFFUSÉ PAR LE QUARTZ (Secondary Radiations in the Light diffused by Quartz).— J. Cabannes. (*Comptes Rendus*, 14th January, 1929, V. 188, pp. 249–250.)

The writer has suggested, in his paper on the polarisation of the secondary radiations diffused by liquids, that the action of the light on a molecule depends on the orientation of the latter (*cf.* Abstracts, 1928, V. 5, p. 691).*

The present paper deals with experiments on crystals, in which the molecules are oriented in a small number of fixed directions.

ON THE MAGNETOSTRICTION OF A SINGLE CRYSTAL OF NICKEL.—Y. Masiyama. (*Sci. Report, Tôhoku Univ.*, August, 1928, V. 17, No. 5, pp. 945–961.)

"In all directions, the longitudinal effect is always contraction for all fields. . . . The transverse effect is just the reverse of the longitudinal one. . . . The magnetic contraction of ordinary nickel is . . . a mean value of contractions in different orientations of the microcrystals constituting the nickel." In English.

THE MAGNETO-RESISTANCE EFFECT IN SINGLE CRYSTALS OF NICKEL.—S. Kaya. (*Sci. Report, Tôhoku Univ.*, September, 1928, V. 17, No. 6, pp. 1027–1037.)

In English. The change in electrical resistance of single crystals of nickel when placed in a magnetic field parallel or perpendicular to the direction of the current was measured.

* An analogous hypothesis has already accounted for the polarisation of fluorescence. *Cf.* F. Perrin, *Journ. de Phys.*, 1926.

RESISTANCE AND THERMO-ELECTRIC PHENOMENA IN METAL CRYSTALS.—P. W. Bridgman. (*Proc. Nat. Acad. Sci.*, December, 1928, V. 14, pp. 943–946.)

SUR LES DIRECTIONS D'ÉMISSION DES PHOTO-ÉLECTRONS (The Direction of Emission of Photoelectrons.)—P. Auger. (*Comptes Rendus*, 10th December, 1928, V. 187, pp. 1141–1142.)

DÉTERMINATION DU RÔLE DE LA LUMIÈRE DANS LES RÉACTIONS CHIMIQUES THERMIQUES (Determination of the part played by Light in Thermal Chemical Reactions).— J. Perrin. (*Génie Civil*, 1st December, 1928, V. 93, p. 535.)

"The part taken by light in a purely thermal reaction is, for each reagent, equal to the amount of fluorescence yielded by that reagent under the conditions under which it finds itself."

ANGULAR DISTRIBUTION OF INTENSITY OF RESONANCE RADIATION.—R. W. Gurney. (*Proc. Nat. Acad. Sci.*, December, 1928, V. 14, pp. 946–951.)

ÜBER ELEKTRONENBEUGUNG IN EINEM GERITZTEN GITTER (Electron Diffraction at a Scratched Grid).—E. Rupp. (*Zeitschr. f. Phys.*, 16th November, 1928, V. 52, No. 1/2, pp. 8–15.)

Hitherto, electron diffraction has been with crystals as grids. These experiments show not only that mechanically made metallic grids give diffraction, but also that the de Broglie wavelength relation holds good (within the limits of error—±2 per cent.—of the test).

HOW MICHELSON SUPPORTS EINSTEIN. (*Sci. News-Letter*, 17th November, 1928, V. 14, pp. 303–304.)

Since Michelson's recent repetition of the Michelson-Morley experiment resulted in the detection of a fringe shift less than a 500th of that calculated for drift through the ether, and only a 10th of the small effect found at the first trial, he concludes that it is due to experimental errors, and that the positive result found by Miller was due to some other cause. Michelson, therefore—it is stated—has now joined the ranks of the relativists, though still maintaining his belief in the existence of the ether.

MISCELLANEOUS.

A NOISE TESTER.—(*The Engineer*, 18th January, 1929, V. 147, p. 71.)

Description of the Noise Tester made by the M.L. Magneto Company for giving a quantitative measure for noises such as those emitted by ball bearings, gear-boxes, exhaust noises, and the like. Three 3-electrode valves are used, the indicating being by a milliammeter.

THREE-ELECTRODE VALVES USED IN CHEMICAL TITRATING PROCESSES.—B. Kamienski. (*Bull. Acad. Polon. Sci. et Lettres*, January/February, 1928, pp. 33–60.)

In a titration method in which the solution is continually stirred and circulated through a curved

tube, containing a "sheltered" electrode near each end, the end-point is indicated by a pronounced rise in P.D. at the two electrodes which, through the mediation of a valve, is caused to give an audible signal.

AUTOMATIC TITRATION, USING PHOTOELECTRIC CELL AND VALVE AMPLIFIER.—General Electric Company. (*Journ. Scient. Instr.*, February, 1929, V. 6, pp. 74–75.)

Methyl orange is used as the indicator, and the photoelectric cell detects the change of tint and through amplifier and relay shuts off the burette.

SUR UNE NOUVELLE MÉTHODE DE LA MESURE DE LA VITESSE DES FLUIDS BASÉE SUR L'EMPLOI D'OSCILLATEURS À LAMPE (A New Method of Measuring the Velocity of Fluids, using Valve Oscillators).—P. Dupin. (*Comptes Rendus*, 18th February, 1929, V. 188, pp. 546–548.)

The flow exerts a pressure (counterbalanced by a spring) which varies a capacity or self-inductance in an oscillating circuit. By zero beat-note methods this variation is determined. Several advantages over other methods (Pitot tube, etc.) are mentioned—one being a linear calibration.

ENREGISTREMENT OSCILLOGRAPHIQUE DES VARIATIONS INSTANTANÉES DE LA PRESSION DANS LES CANALISATIONS D'EAU. MÉTHODE DU QUARTZ PIÉZOÉLECTRIQUE (Oscillographic Registration of Instantaneous Pressure Variations in Water Systems. Piezo-electric Quartz Method).—R. Hocart. (*Journ. de Phys. et le Rad.*, No. 6, 1928, V. 9.)

PHOTOELECTRIC CONTROL WITH MIRROR READING INSTRUMENTS.—K. Lark-Horovitz and G. W. Sherman. (*Phys. Review*, No. 2, V. 32 p. 328.)

A photoelectric cell is screened by a plate with three sections; the mid-section is half-opaque, the others respectively clear and opaque. The relay circuit is arranged to be at rest when the mirror of the galvanometer directs its ray on to the mid-section. An electric oven thus controlled, with a range of variation 80–600 degrees, keeps constant within 1 degree. A Röntgen apparatus can similarly be kept constant, using a H.T. mirror electrometer.

SOUND RECORDING WITH THE LIGHT VALVE.—D. MacKenzie. (*Bell Tech. Journ.*, January, 1929, V. 8, pp. 173–183.)

The sound-recording here described is of the variable density type, based on the use of the Bell Laboratory Light Valve. This consists essentially of a loop of duralumin tape formed into a slit at right angles to a magnetic field; currents flowing in the loop cause the slit to open and close and thus to let more or less light pass.

SYNCHRONISATION AND SPEED CONTROL OF SYNCHRONISED SOUND PICTURES.—H. M. Stoller. (*Bell Tech. Journ.*, January, 1929, V. 8, pp. 184–195.)

The important problem now (in systems where the sound-reproducing mechanism is coupled mechanically to the picture projector) is to ensure that this synchronisation does not affect the pitch of the sound to a degree noticeable by a musical ear. A change, made abruptly, of one half of 1 per cent. can be noticed.

The paper describes valve frequency-bridge control circuits, and also the modified Michalke electric gear system for interlocked linking of sound-recorder and picture-recorder when these are at a distance.

SPEAKING TO EARTH FROM AN AEROPLANE.—(*Rad. Engineering*, February, 1929, V. 9, p. 48.)

Tests made by an American firm show that from an aeroplane equipped with a special loud speaker, flying at full throttle at 500 feet, the pilot's voice can be plainly heard and understood over an area of "about one-half mile square."

HEIGHT OF AEROPLANE ABOVE GROUND BY RADIO ECHO.—E. F. W. Alexanderson. (*Rad. Engineering*, February, 1929, V. 9, pp. 34–35.)

A fuller description of the methods referred to in March Abstracts, p. 168. Either one oscillator can be used, in which case the operator periodically changes the wavelength by—say—8 per cent. by pressing a key, and thus obtains two graphic curves which show the phase relation of the two waves, the amplitude of the echo indication having to be taken into account also, to avoid ambiguity; or two oscillators and two aerials can be used, in which case maxima of beat-frequency will be produced at certain heights.

BESEITIGUNG DER DURCH HOCHFREQUENZHEILGERÄTE HERVORGERUFENEN STÖRUNGEN DES RUNDFUNKEMPFANGES (Prevention of Interference with Broadcast Reception due to H.F. Medical Apparatus).—(*E.T.Z.*, 14th March, 1929, p. 394.)

PHYSICAL AND OPTICAL SOCIETIES' EXHIBITION: DESCRIPTION OF THE EXHIBITS.—(*Journ. Scient. Instr.*, February, 1929, V. 6, pp. 51–78.)

ÜBER HERZTÖNE UND HERZGERÄUSCHE (Heart Tones and Sounds).—K. Posener and F. Trendelenburg. (*Zeitschr. f. tech. Phys.*, December, 1928, pp. 495–499.)

Auscultation by condenser-microphone—illustrated by numerous oscillograms.

EXPLICATION DES EFFETS THÉRAPEUTIQUES DES CIRCUITS OSCILLANTS OUVERTS SUR L'ORGANISME DES ÊTRES VIVANTS (Explanation of the Therapeutic Effects of Open Oscillating Circuits on the Organism of Living Creatures).—G. Lakhovsky. (*Comptes Rendus*, 25th February, 1929, V. 188, pp. 657–658.)

The writer recalls his early work on the healing effects, on cancer in plants, of waves of the order of 2 m. Seidel has shown recently that milk, etc., can

be sterilised by waves of 1.5—3 m. Esau has just shown that mice inoculated with tuberculosis can be cured by 2 m. waves. The paper then deals with the writer's results with open insulated spirals surrounding diseased plants, unexcited by any oscillations other than those picked up from the atmosphere. His results in curing plant tumours have since been successfully repeated by other workers. These open circuits have been tested on human maladies, with results of marked improvement and sometimes complete cure in what were considered incurable cases. He attributes their effect to their being excited, to oscillate at their own natural frequencies (0.35—2 m.), by the numerous and varied electromagnetic oscillations present nowadays in the atmosphere—due to arcs, magnetos, dynamos and motors, rectifiers, lightning, wireless stations, and the "cosmic rays." The therapeutic effects may be similar to those produced by X-rays, ultra-violet light, radium, etc., but are less violent and more permanent owing to the constancy and feebleness of the radiations. The writer refers to the pioneer work in H.F. therapeutics of d'Arsonval, who on p. 659 recalls his first results.

Quelques Statistiques sur la Mortalité et l'Âge d'Élection des Membres de l'Académie (Some Statistics on the Age at Death and Age at Election of the Members of the French Academy).—C. Richet. (*Comptes Rendus*, 25th February, 1929, V. 188, pp. 591-594.)

For the physicists, the statistics show that the average life is 70 years (Becquerel reached 90, while Malus died at 37); the average age at election—taken from members still alive—is 57, whereas for past members since 1800 it was 48. Gay Lussac was the youngest—at 28.

Joffé's Untersuchungen über die elektrische Durchschlagsfestigkeit (Joffé's Investigations into Dielectric Strength).—A. Smekal. *Entgegnung* (Reply). A. Joffé. (*Naturwiss.*, No. 39, 1928, V. 16, pp. 743–745.)

An argument concerning Joffé's interpretation of his results on the high dielectric strength of very thin films. Smekal refuses to accept the "ionisation by collision" idea.

Contact Effects between Electrodes and Dielectrics.—B. G. Churcher, C. Dannatt and J. W. Dalgleish. (*Journ. I.E.E.*, February, 1929, V. 67, pp. 271–290.)

Among the results of this research are the following: Barlow's view, that "such materials as slate, red fibre, paxolin and celluloid can only be classed as dielectrics in virtue of their high contact resistance," is exaggerated; when testing dielectrics with mercury electrodes, contact effects of a certain order are to be anticipated, but these are only important in relation to that class of materials known as "semi-conductors," in which the volume resistivity is low. The importance of these effects in industrial tests upon commercial dielectrics is shown to be small provided that specimens of adequate thickness are employed. An endeavour is made to assess the significance of the contact effect in relation to dielectric measurements of a fundamental nature. Contrary to the general idea that mercury electrodes are the ideal arrangement for testing dielectrics, two methods of obtaining better contact are found: the spraying of zinc by Schoop's "metallisation" process (February Abstracts, p. 112), and, better still, the use of a graphited surface backed with mercury. More finely divided graphite without mercury backing (only tested on D.C. at present) gives better contact than mercury alone.

Silver Sulfluoride Crystals as Rectifiers (Silver-wire Contact).—A. Hettick. (*Z. anorg. Chem.*, 1927, V. 167, p. 67.)

Photometry of Therapeutic Lamps.—D. T. Harris. (*Journ. Scient. Instr.*, January, 1929, V. 6, pp. 2–7.)

A rapid method of measuring the ultraviolet emission from luminous sources is described, involving the use of a photoelectric cell, thermionic valve and a microammeter.

Coronaphone Testing Instrument for Detection of incipient Trouble in a Transformer. (*Gen. Elec. Review*, January, 1928, V. 32, pp. 45–46.)

It is known that various types of insulation trouble have their characteristic noise. By the use of the coronaphone the normal hum is filtered and suppressed, while the remaining noise is amplified and is used either to listen to or to operate a relay.

Use of Thyratron for Furnace Temperature Control. (*Gen. Elec. Review*, January, 1929, V. 32, p. 37.)

The thyratron is stated to be the best means yet found for amplifying the feeble impulses from thermocouples or resistance thermometers, to control the large amounts of power used for furnace heating. The variations in plate current are enough to operate a contact-maker requiring two or three amperes. Very delicate mechanical devices have hitherto been used as relays.

Recording Colorimeter.—(*Gen. Elec. Review*, January, 1929, V. 32, p. 38.)

This apparatus automatically, rapidly, and accurately measures and records the wavelengths of colours of any substance. The fundamental idea of the mechanism is that when the standard material and the specimen, one after the other, reflect different amounts of light of a particular wavelength, a ray of pulsating intensity is produced which (through the mediation of a photoelectric cell) runs a small motor whose motion works a shutter and automatically finds a position on the spectrum where—owing to equal reflection—the pulsations cease. A complete colour analysis takes less than a minute.

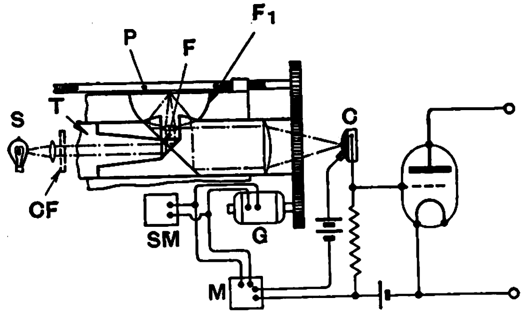
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

PICTURE TRANSMISSION.

(*Application date, 27th July,* 1927. *No.* 300148.)

In order to facilitate amplification, the photoelectric cell used to scan the picture is subjected to an alternating current, so that its effective output is modulated periodically, independently of the light-and-shade effects. The resulting picture has a background of dots evenly and regularly spaced



and grouped according to the frequency of modulation. Further, in order to ensure synchronism between transmitter and receiver, constant-frequency generators controlled by a tuning fork or piezo crystal are used for driving the scanning apparatus.

In the present invention the means for driving the scanning apparatus is so linked with the modulating source that a definite ratio is maintained between these two frequencies in operation. Light from a source *S* is focussed along a tube *T* and reflected at right angles by a prism *F* on to the picture *P*. The reflected light is collected by a mirror and prism F_1 and focussed on to a photoelectric cell *C*. The rotating and traversing mechanism for the picture-carrying tube is driven through gearing from a motor *G*, whilst the independent modulation frequency is applied to the cell *C* from a source *M*. Both *M* and *G* are driven in turn from a common constant-frequency source *SM* controlled by tuning fork or piezo crystal. The motor *G* is directly connected to the supply *SM*, whilst the modulator *M* comprises a frequency-changer which can be adjusted to give an output definitely related in frequency to the speed of the motor *G*.

Patent issued to G. M. Wright and S. B. Smith.

EXPONENTIAL HORNS.

(*Application date, 9th August,* 1927. *No.* 302199.)

In designing an acoustic horn it is desirable (*a*) that the proportion of available mechanical energy in the diaphragm converted into sound shall be a maximum, and (*b*) that this proportion shall be the same for all audible frequencies. The requirement under (*a*) depends upon the area of the initial throat opening of the horn, whilst that under (*b*) depends upon the rate of expansion of the bore, and the overall length of the horn.

In the exponential type of horn, the area of the bore is made to increase by a constant percentage per unit length along the axis from throat to mouth. Theoretical considerations show, however, that the smaller this percentage is made, the more uniform is the loading on the diaphragm for the various frequencies in question. Also in order to minimise end-reflection from the mouth of the horn, the flare should be as large as possible. Obviously both these requirements involve a long horn.

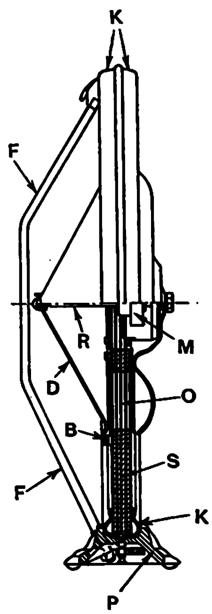
According to the present invention, the same benefits are secured from a comparatively short horn, by making the percentage increase in bore area per unit length a gradually increasing quantity, from throat to mouth, instead of being a constant quantity as in the standard design.

Patent issued to R. E. Lloyd-Owen and T. Watson.

LOUD SPEAKERS.

(*Application date, 10th September,* 1927. *No.* 301960.)

The main structure consists of a disc *S* built up from several thicknesses of corrugated paper or strawboard, with the corrugations running in different directions. The magnetic movement *M* is mounted at the centre of the disc, but is cushioned or isolated from it by thick felt or rubber. A conical diaphragm *D* is vibrated by the magnet through a light stiff rod *R*.



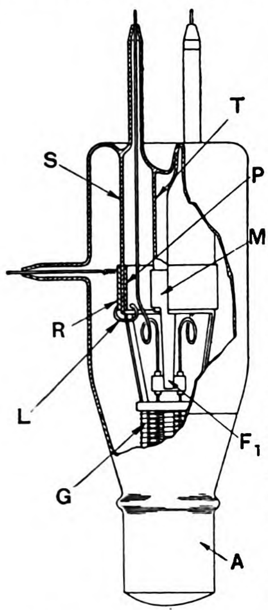
The edge of the diaphragm *D* abuts closely against the surface of the disc *S* to prevent any air leakage, a sound insulating buffer or ring *B* being interposed as shown. Openings *O* are formed in the main disc inside the area covered by the diaphragm to allow free passage of air. The outer edges of the main discs are bound or clamped together between sheet-metal rings *K*. The whole structure is mounted on a heavy base-plate *P*, which also supports a spider frame *F* consisting of two splayed metal rods which serve to strengthen the structure from top to bottom.

Patent issued to Sterling Telephone Co., Ltd., N. Blades and J. R. Beard.

HIGH-POWERED H.F. GENERATORS.

(*Application date*, 27*th August*, 1927. *No.* 301355.)

The dielectric strain on the vitreous material of a short-wave transmitting-valve, consuming say 10 kilowatts and generating at a wavelength of 25 metres or less, frequently leads to excessive heating, electrolysis, and consequent destruction of the bulb. The inventors have discovered that the strain can be more equally distributed, and therefore reduced to safe dimensions by fitting a metal screen inside the bulb between the grid collar and the filament leads.



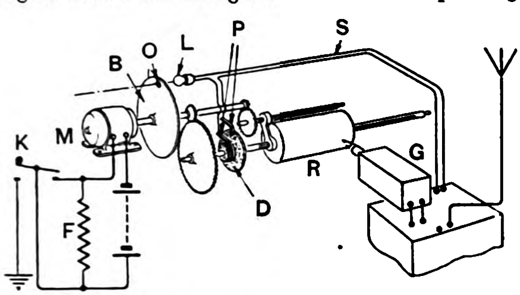
The Figure represents a power valve fitted with a fused-on metal anode *A*. The grid *G* is suspended from a metal ring *R* which grips the re-entrant stem *S* of the bulb. The support F_1 for the filament is carried by a collar *M* fixed to a central stem *T*. The protective screen *P* consists of a ring of copper gauze or sheet nickel bent around and expanded into position inside the bulb. It is metallically connected to the grid collar *R* by a short lead *L*. In this way the inside and outside of the glass are both maintained at the same potential level, and the risk of damage by fracture is minimised.

Patent issued to Standard Telephones and Cables, Ltd., and W. T. Gibson.

PICTURE-TRANSMISSION SYSTEMS.

(*Convention date* (*U.S.A.*), 25*th July*, 1927. *No.* 294546.)

At the transmitting end, a special synchronising signal is sent out at regular intervals corresponding



to each complete rotation of the picture-carrying drum. At the receiving end, this signal is separated out from the light-modulated signals, the latter being fed to the recording-drum *R* through an oscillograph *G* in known manner. The synchronising signals will pass through leads *S* to energise a lamp *L* so long as the contacts *P* occupy a certain segment on the surface of a disc *D*. This disc is keyed to the shaft of the recording drum *R* and is driven by the motor *M*.

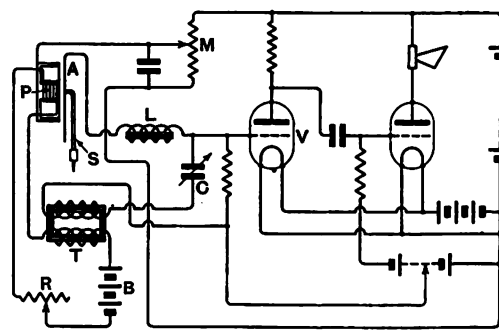
If the rotation of the drum *R* is exactly in step with that used at the transmitting station, the position of the flicker from the lamp *L*, as viewed through a hole *O* in the rotating disc *B*, will appear to remain stationary. If one motor is either leading or lagging the other, the direction of drift is indicated by the stroboscopic movement of the lamp-image, thus enabling the operator to accelerate or slow down the motor *M* as necessary. The local speed control consists of a field resistance *F* and a short-circuiting key *K* manipulated by the operator.

Patent issued to The British Thomson-Houston Co., Ltd.

GRAMOPHONE PICK-UPS.

(*Application date*, 24*th February*, 1928. *No.* 302838.)

Electrostatic and electromagnetic action is combined in the same pick-up, the resultant voltage fluctuations being applied to the grid of the amplifier in parallel, the object being to increase the fidelity



of response towards the upper and lower limits of audibility. The outer diaphragm *A* of the pick-up *P*, when vibrated by the stylus needle *S*, co-acts with a flat annular pole-piece (*a*) to alter the effective capacity of the condenser system, and (*b*) to vary the magnetic flux across the pole-pieces.

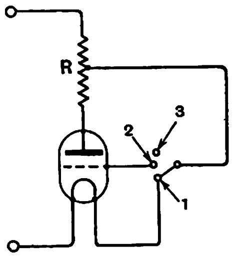
The electrostatic effect is applied directly to the grid of the amplifier *V* through a choke *L*, whilst the magnetic variation is applied across a step-up transformer *T*. The initial voltage on the condenser plates of the pick-up is derived from a tapping *M* on a potentiometer fed from the high-tension battery. The windings of the magnetic pick-up are energised from a battery *B* through a variable resistance *R*. The choke *L* prevents the shunting of high-frequency magnetic impulses away from the grid, whilst the condenser *C* serves a similar purpose in the case of low-frequency impulses due to the electrostatic action of the pick-up.

Patent issued to H. Andrewes and Dubilier Condenser Co. (1925), Ltd.

GAS-FILLED DISCHARGE TUBES.

(*Application date*, 29*th August*, 1927. *No.* 301763.)

The Figure shows a convenient switch arrangement for controlling a discharge tube of the type in which an incandescent filament is used to start the discharge. Once the discharge has been started, it is self-sustaining, the filament being switched out of circuit. When the switch is on contact 1, current from the mains is supplied through a portion of the common resistance *R* to heat the filament. The switch is next moved over to point 2 where the discharge is initiated by the biasing potential so applied to the control electrode. Once the discharge stream is established, the switch is moved over to the idle point 3.

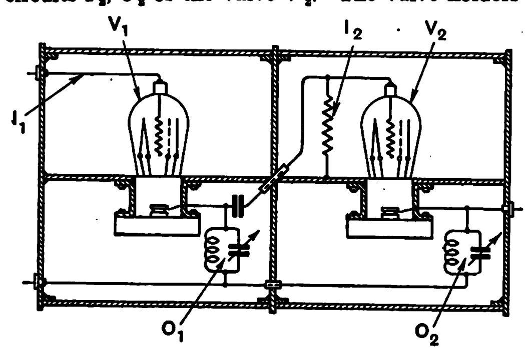


Patent issued to S. G. S. Dicker.

SCREENING AMPLIFIER CIRCUITS.

(*Convention date* (*U.S.A.*), 8*th February*, 1927. *No.* 285020.)

The use of a screened-grid valve whilst preventing capacity coupling across the internal electrodes does not eliminate reaction due to the proximity of external circuit components. For this additional screening-means are necessary. The Figure shows two H.F. valves enclosed in a metal casing subdivided into four compartments, so as to screen not only the input circuit I_1 of the valve V_1 from the output circuit O_1, but also the corresponding circuits I_2, O_2 of the valve V_2. The valve holders



are suspended from the intermediate partition so that the valves can be easily removed without disturbing the circuit connections.

Patent issued to The British Thomson-Houston Co., Ltd.

MULTIPLE VALVES.

(*Convention date* (*Germany*), 19*th July*, 1926, *No.* 274514.)

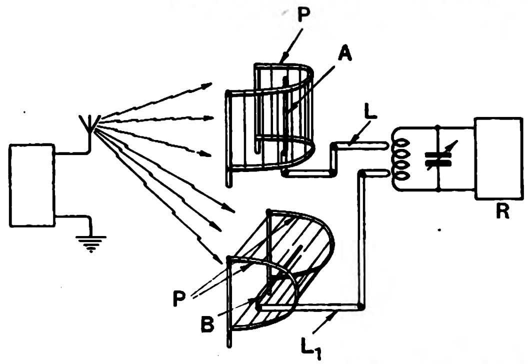
In a valve of the type in which several complete amplying stages are housed in the same glass bulb, special screening elements are fitted, more especially around the last stage, in order to prevent the humming or ringing noise due to free or uncontrolled electrons which periodically "load" the glass wall of the tube. In each case the screen consists of a metallic cylinder surrounding the ordinary electrode system but spaced away from the inner wall of the bulb, and connected to a point of fixed potential. Alternatively, the ordinary "getter" coating of magnesium on the inside wall of the bulb may be connected by a special fused-in lead to a point of fixed potential for the same purpose.

Patent issued to Dr. S. Loewe.

PREVENTING FADING.

(*Application date*, 19*th September*, 1927, *No.* 302634.)

Fading is attributed to the fluctuating effect of the Heaviside layer upon the polarisation of the transmitted wave. For instance, signals transmitted with a vertical polarisation often reach the earth, after reflection, with a predominant horizontal polarisation, in which case there is no



appreciable pick-up by an aerial designed to receive the former type of wave.

To compensate for this effect, two or more receiving aerials *A*, *B* are spaced apart, but are linked to a common receiver. *R*. The aerial *A* is arranged with its axis vertical, whilst *B* is horizontal, both being associated with a suitable reflecting system *P*. Should fluctuations occur in the polarisation of the incoming wave, energy missed by one aerial will be received upon the other, and *vice versa*. The length of each of the combining lines *L*, L_1 is such that the received energy reaches the final collecting circuit in correct phase. For short-wave working, both receiving aerials *A*, *B* are preferably elevated several wavelengths above the ground.

Patent issued to Standard Telephones and Cables, Ltd.

TESTING ACCUMULATORS.

(*Application date* 16*th November*, 1927, *No.* 302784.)

Near the top of the accumulator casing is a small self-contained chamber which is perforated at the bottom to allow free passage of the electrolyte. The chamber contains one or more specific-gravity balls, so that it serves as a permanent hydrometer. The condition of the electrolyte can be estimated at any time from the level of the floating balls as seen through a small glass panel let into the main casing.

Patent issued to G. H. Trotter.

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VOL. VI. JUNE, 1929. No. 69.

Editorial.

Gas-filled Rectifying Valves.

TO prevent any misunderstanding we may say at once that the valves to which we wish to refer are not intended for the detection of radio signals but for the rectification of large alternating currents. It is well known that the presence of gas in a valve enables the applied voltage to send a larger current through it than is possible if the gas is not present, but it has been thought impossible to make use of this fact because of the rapid disintegration of the cathode due to its bombardment by the gaseous ions. Research carried out by A. W. Hull and other members of the laboratory staff of the General Electric Company of Schenectady has shown, however, that under certain conditions this disintegration does not take place. "Cathodes have been made which furnish 1,500 amperes emission under conditions which promise long life, and cathodes with a normal emission of 10,000 amperes appear practical." In order that disintegration should not take place, the velocity with which the gaseous ions strike the cathode must not exceed a certain value corresponding for the inert gases to a voltage drop of from 20 to 25 volts. Since lower voltages than this are capable of ionising the gas, it is possible to pass large currents without disintegration of the cathode by ensuring that the cathode drop lies between the disintegration and the ionisation voltage. This can be ensured by suitably adjusting the resistance of the circuit. The maximum current is limited only by the size of the cathode, and the maximum voltage which can be rectified is limited by the arcing back which will occur in any gaseous space if the voltage exceeds a certain value, but the rectifiers described by A. W. Hull operate satisfactorily at 10,000 volts D.C. output.

If a thorium-coated cathode is used in a two-electrode valve containing argon at a pressure of 0.1 mm. and the anode voltage is gradually increased, the current reaches a maximum at about 25 volts and falls rapidly as the voltage is still further increased. It is surprising that at 50 volts the current passing is less than a tenth of what it was for 25 volts. This has been explained by Langmuir by assuming that the emission of electrons is due to a thin layer of thorium atoms on the surface of the cathode and that these atoms are actually removed by the bombardment of gaseous ions if these latter strike them with sufficient velocity. Hence the secret of making such a rectifier with good emission and long life would

appear to lie in keeping the voltage drop below about 25 volts.

The efficiency of the cathode as an emitter of electrons has been greatly increased by the introduction of the heat-insulated cathode. In the ordinary separately-heated cathode the emission takes place from the outside of the internally-heated cylinder. This is thermally inefficient because the emissive coating radiates heat about five times as fast as a similar surface of polished nickel. In the heat-insulated cathode the cylinder is open at the end and coated with barium oxide or other emissive coating on the inside, the heating filament being enclosed in a smaller central tube. Not only is the outside of the nickel cylinder polished, but it is surrounded by two further nickel cylinders with small annular gaps, thus greatly reducing the loss of heat. Even the open end of the cylinder is occupied by a number of radial vanes coated with active material. Such a heat-conserving cavity would be useless as a cathode in a high-vacuum valve because it would become choked with an electron space charge, but in the gas-filled valve the space charge is neutralised by the gaseous ions which enter the cylinder. By these ingenious devices the efficiency has been increased to 24 times that of the ordinary cylindrical cathode, so that at a temperature of 1,000 deg. K. the emission per watt of heating has been increased from 24 to 600 milliamperes. It is estimated that such a cathode should have a life of over seven years; some have been in continuous operation for six months without any noticeable change.

As an example of the importance of the vapour pressure in a low-voltage mercury vapour rectifier with a barium-coated nickel-cylinder cathode, it is stated that with a vapour pressure of 1 to 3 mm., the rectifier operated at 5 amperes for 4,000 hours, whereas with a pressure of 0.01 mm. the life was less than 20 hours. This is due to the protective action of the gas in preventing evaporation of the active material. This type of rectifier can only be used for low voltages; for voltages above 1,000 the gas pressure must be so low in order to prevent arcing back that its protective action is negligible.

Very high voltages require careful spacing and design of electrodes with respect to the glass bulb. As Hull points out, the electric field within the bulb is modified by the presence of the gaseous ions and may be very different from that which would exist in a vacuum. The ions tend to modify the field in such a way that the sparking potential is reduced; if the gas pressure is high they tend to shorten the effective length of the path between the electrodes, whereas if the gas pressure is so low that the length of gap which would give the minimum sparking voltage is longer than the actual distance between the electrodes, then the ions actually modify the field so as to lengthen the effective sparking path. A limit may be set to this by the dimensions of the glass bulb.

In the paper describing these researches, which was read by A. W. Hull in New York in May last, a description is also given of a rectifier with an auxiliary electrode or grid which can be used to start the rectifier This has been given the name of " thyratron " (Greek *θυρα*—a door), but we do not propose to discuss this device here. It would appear that the day of the soft valve is not past and that there still remains much to be discovered in the fruitful field of thermionics.

G. W. O. H.

Radio Frequency Transformers as Applied to Screen-grid Valves.

By S. Butterworth, M.Sc.

IN the orthodox theory of radio frequency transformers* it is usually assumed that the primary of the transformer is working in a circuit of high resistance. A small E.M.F. of radio frequency is impressed on this circuit and the secondary of the transformer is tuned by means of a condenser. It is then shown that if the transformer coupling is such that the load due to the primary circuit doubles the apparent resistance of the secondary circuit a maximum E.M.F. will be obtained across the tuning condenser, and, further, that this maximum E.M.F. will increase as the square root of the magnification of the secondary coil.

In practice, the primary of the transformer is in the anode circuit of a valve and it is found that the theory can only be applied successfully if the input circuit of the valve is aperiodic. If the input circuit is another tuned circuit then any attempt to use an efficient secondary circuit only results in a persistent howl from the whole system.

This state of oscillation is, of course, due to reaction of the secondary on the primary *via* the grid-plate capacity of the valve, and may be countered by the use of a neutrodyning arrangement. Now neutrodyning is a somewhat delicate operation, and when the screen-grid valve was introduced it was hoped that the inter-electrode capacity would be reduced to such a value that efficient secondary circuits could be employed to give stable systems having high magnifications. By using screen-grid valves of special construction, Hull and Williams (*Phys. Rev.*, p. 432, Vol. 27, 1926) were able to reduce the inter-electrode capacity to as low a value as 0.006$\mu\mu$F. as compared with 2$\mu\mu$F. or more for the ordinary triode. With commercial valves of the screen-grid type, however, it is more usual to have values of 0.05 to 0.1$\mu\mu$F. for the grid-plate capacity. It is important, therefore, to find how to make the best use of radio frequency transformers while accepting capacities of the order of 0.1$\mu\mu$F. and without having to make use of neutrodyning arrangements. Also if the receiving set is to be used over the range 300 to 600 metres the stability must be assured for a shorter wavelength than 300 metres and the magnification must be reasonable in the most unfavourable case, that is, at the longest wavelength, 600 metres. We shall, therefore, study the case in which the tuning condensers can be varied in the ratio 10 to 1, the circuit constants being such that the system is just stable at the smallest condenser settings while the magnification at the highest condenser settings will be taken as a measure of the performance of the system. It will be shown that stability may be brought about in a variety of ways, but that the most efficient way is by reducing the primary turns of the transformer while still employing lightly damped tuned circuits. Since the tuned anode is, in effect, a transformer of one to one ratio we can settle the question of the relative efficiencies of tuned anodes and radio frequency transformers and find that the latter system is the one that should be employed.

Simplifying Assumptions.

In any theory involving grid-plate capacities of valves so many factors have to be taken into account that the principles are apt to become hidden in a mass of mathematical formulæ. The stability or otherwise of the system depends not only on the constants of the anode circuit, but also on those of the input circuit. The circuit to be considered is that shown in Fig. 1. The tuned input and output circuits are assumed in the first place to be electrically similar, having equal inductances L, equal capacities C and equal losses represented by the parallel conductances σ. The working pulsatance

* See, for example, Dr. McLachlan's article under the above title in *E.W. & W.E.*, p. 597, Vol. IV, 1927.

(frequency multiplied by 2π) is ω and the two condensers C are tuned simultaneously, so that the common natural pulsatance of the two circuits is $\omega_0 = 1/\sqrt{LC}$ and in the equations is always supposed to be in the neighbourhood of ω. We therefore write $p = \omega - \omega_0$ and assume p/ω_0 to be small.

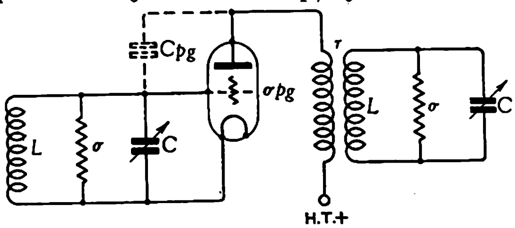


Fig. 1.

The vector admittance of both input and output circuits may then be written

$$\beta = \omega_0 C(\psi + jx) \quad .. \quad (1)$$

in which j is the operator rotating through a right angle and is treated algebraically as the imaginary $\sqrt{-1}$, $\psi = \sigma/\omega_0 C$ and is the circuit power factor while $x = 2p/\omega_0$ and may be called the tuning factor.

For simplicity the transformer will be assumed to have perfect coupling and the ratio of secondary to primary turns will be denoted by r. The output circuit of Fig. 1 may then be replaced by its equivalent anode circuit which has admittance $r^2\beta$, while the actual output voltage is r times that deduced for the equivalent anode circuit. The modifications to theory owing to imperfect coupling are discussed in the Appendix.

As regards the valve, we will suppose it to have infinite anode impedance, grid-plate conductance σ_{pg}, grid-plate capacity C_{pg} and we will denote the vector admittance linking grid and plate by a so that

$$a = j\omega_0 C_{pg} \quad .. \quad (2)$$

The assumption of infinite anode impedance means that not only are the variations of anode current independent of anode voltage, but also that the plate filament capacity of the valve can be neglected. In practice the valve impedance acts as a shunt across the admittance $r^2\beta$ so that it is justifiable to neglect it if r is sufficiently large. It will be seen that with existing screened grid valves the value of r necessary to secure stability when using lightly damped circuits is so large that the assumption is justified, but this assumption would break down in the case of valves of negligible grid-plate capacity, that is, anode impedance is of importance in the theory as developed by Dr. McLachlan. Even in this case it would appear that the effect of plate-filament capacity is of more importance than that of plate-filament resistance and this is a factor usually neglected in presenting the orthodox theory. Its effect is chiefly on the optimum coupling condition, but there is also a tendency for a rejector effect to appear when the primary of the transformer gets into resonance with the plate-filament capacity.

Input Admittance of Valve and Voltage Ratio.

Let a high frequency voltage v_g be applied to the grid of the valve and let the resulting plate voltage be v_p. Then from Fig. 2, the current passing direct from grid to plate is $a(v_g - v_p)$ of which $\sigma_{pg}v_g$ flows through the valve from plate to filament, while $r^2\beta v_p$ flows through the anode circuit. Hence

$$a(v_g - v_p) = \sigma_{pg}v_g + r^2\beta v_p$$

giving for the voltage ratio

$$v_p/v_g = -(\sigma_{pg} - a)/(r^2\beta + a) \quad .. \quad (3)$$

while the input admittance is

$$\beta_g = a(1 - v_p/v_g) = a + a(\sigma_{pg} - a)/(r^2\beta + a) \quad .. \quad (4)$$

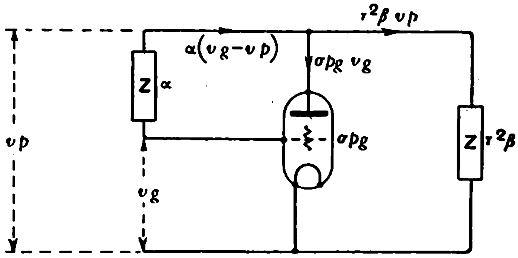


Fig. 2.

Now a/σ_{pg} and $a/r^2\beta$ are both small, so that approximately

$$v_p/v_g = -\sigma_{pg}/r^2\beta \quad .. \quad .. \quad (5)$$
$$\beta_g = a\sigma_{pg}/r^2\beta \quad .. \quad .. \quad (6)$$

The above input admittance is, of course, that due to the grid-plate capacity. There may be a further input admittance due to grid current and grid filament capacity.

These are both supposedly included in the input circuit constants.

Overall Voltage Magnification.

In its simplest case imagine the input circuit coil to be a frame aerial coil. Then the input voltage v_1 is that induced in the frame by the incoming signal and is of the form

$$v_1 = K\sqrt{L} = K/\omega_0\sqrt{C} \quad .. \quad (7)$$

in the neighbourhood of resonance where K depends on the strength of the signal, on the size and shape of the frame, but not on the number of turns.

It is then readily shown that the impressed grid voltage is given by

$$v_g = v_1/j\omega_0 L(\beta + \beta_g) \quad .. \quad (8)$$

Hence, using (5) and (6) and multiplying by the transformation ratio we obtain for the output voltage,

$$v_0 = -r\sigma_{pg}v_1/j\omega_0 L(r^2\beta^2 + a\sigma_{pg}) \,.. \quad (9)$$

Then by (1), (2) and $\omega_0^2LC = 1$,

$$v_0/v_1 = -r\sigma_{pg}/j\omega_0 C\{r^2(\psi + jx)^2 + jC_{pg}\sigma_{pg}/\omega_0 C^2\} \quad (10)$$

The form of the equation is further simplified by writing

$$y = x/\psi = 2p/\omega_0\psi \,.. \quad .. \quad (11)$$
$$G = C_{pg}\sigma_{pg}/2r^2\omega_0 C^2\psi^2 \quad .. \quad (12)$$

and then (10) becomes

$$v_0/v_1 = \sigma_{pg}/jr\omega_0 C\psi^2\{1 - y^2 + 2j(G + y)\} \quad (13)$$

This is the fundamental equation for determining the performance of the system in the neighbourhood of resonance.

Stability.

The first essential of any receiving circuit is that it shall be stable throughout the total swing of its tuning condensers. The conditions of critical stability are readily obtained from (13) by equating the real and imaginary parts of the denominator to zero simultaneously. This gives $y = -1$ to determine the frequency of oscillation and $G = 1$ to determine the condition of oscillation. As a system with no grid-plate capacity ($G = 0$) is essentially stable, the condition for stability must therefore be that G is less than unity throughout the whole of the condenser range. Remembering that $\omega_0 = 1/\sqrt{LC}$, (12) shows that G increases as C diminishes, so that at a certain value of C, which we will call C_0, G will reach unity. For any other value of C the value of G will be given by

$$G = (C_0/C)^{\frac{3}{2}} \quad .. \quad (14)$$

showing that the system will be stable so long as C is greater than C_0. Our method of securing stability is therefore to assign a value to C_0 at or below the bottom of the condenser scale and so choose our circuit constants that

$$\sigma_{pg}C_{pg}L^{\frac{1}{2}}/r^2C_0^{\frac{3}{2}}\psi^2 = 2 \quad .. \quad (15)$$

Thus to take a practical case, suppose we require to work over the 200 to 600 metre band using a condenser varying between 30 and 300$\mu\mu$F. while the valve constants are $\sigma_{pg} = 0.001$ mho, $C_{pg} = 0.1\mu\mu$F. The required value of L is approximately 330μH. which gives resonance at 30$\mu\mu$F. when $\omega = 10^7$ or $\lambda = 188$ metres. Using these in (15) we find the stability condition gives a simple relation between the ratio of the transformer and the power factor of the circuit, namely,

$$r\psi = 0.0745 \quad .. \quad (16)$$

or since the reciprocal of the power factor is the circuit magnification (m),

$$r = 0.0745 \text{ m.} \quad .. \quad (17)$$

The practical meaning of (16) or (17) is obvious. We can use highly efficient tuned circuits or highly damped ones. In the former case, the transformer must have few turns in order to secure the necessary value for r, the secondary turns being fixed by the inductance. Thus if $m = 200$ the primary turns must be 1/15th of the secondary, and since a coil 3in. in diameter and $\frac{3}{4}$in. in winding length requires about 55 turns to secure the above inductance, the number of primary turns that can be used is only about four if stability is to be obtained at the bottom of the condenser scale.

It is to be noted that this result is entirely opposed to the conclusion obtained from the orthodox theory where an optimum is sought without regard to stability. In fact for a screened grid valve of high impedance the number of turns demanded for the primary may well be greater than those on the secondary in order to secure the optimum coupling. If we wish to get this so-called

optimum and yet retain stability we must necessarily work with circuits of high damping, and this may more than wipe out any advantage obtained from the optimum coupling. As to which system is the correct one will appear when we have studied the nature of the overall magnification.

Optimum Conditions.

It is clear that if the system is arranged to have critical stability with the condensers set at 30$\mu\mu$F. the magnifications will be very large at settings just above this point and that the magnification will drop as the capacities are increased. It is therefore advisable to study the magnification where it is least, namely, with the condensers at their highest values of 300$\mu\mu$F. From (14) the value of G is then 0.0316 and from (13) the amplitude of the denominator is proportional to

$$F = \{(1 - y^2)^2 + 4(G + y)^2\}^{\frac{1}{2}} \quad .. \quad (18)$$

This is a minimum for variation of the tuning factor (y) when $y = -y_0$, where y_0 is given by

$$y_0(1 + y_0^2) = 2G \quad .. \quad (19)$$

and the minimum value is

$$F_0 = (1 - y_0^2)\ (1 + y_0^2)^{\frac{1}{2}} \quad .. \quad (20)$$

Using $G = 0.0316$ we obtain $y_0 = 0.0630$ and F_0 is practically unity. Using this result in (13) and also putting $\sigma_{pg} = 0.001$, $r\psi = 0.0745$, $\omega_0 = 3.16 \times 10^6$ (the resonant pulsatance at 300$\mu\mu$F.), $C = 3 \times 10^{10}$ we obtain for the resonant magnification at the upper condenser settings

$$v_0/v_1 = 14.2/\psi = 14.2m \quad .. \quad (21)$$

Since the factor m may be regarded as the magnification due to the input circuit alone we conclude that the magnification due to the screened grid valve plus the high frequency transformer is 14.2 whatever the value of m. This does not mean, however, that there is no need to pay attention to the power factor of the output circuit because the result only holds when the power factors of the two circuits are equal. The more general case is treated in a later section.

It has been shown (McLachlan, *loc. cit.*) that with ordinary neutrodyned valves, magnifications greater than the above are possible, the figures quoted being 15 to 52 according to the type of valve used. It must be remembered, however, that the above figure is the minimum over the whole scale and that the value is possible without recourse to the complications of neutrodyning. Also the value used for the grid-plate capacity may be pessimistic. If this capacity is less, more primary transformer turns may be used and the magnification will then increase as the inverse square root of the value of the grid-plate capacity. With Hull's valve, the magnification should be of the order of 56, and although this figure may not be attainable with commercial valves, yet it should be quite possible to obtain magnifications of the same order as those theoretically possible with neutrodyned triodes.

Comparison with Tuned Anode.

We are now in a position to supply a partial answer to the question as to the relative merits of H.F. transformers and tuned anodes. In the latter case we must make $r = 1$ and then (16) tells us that in order to secure stability ψ must be as large as 0.0745. This is an extraordinarily poor factor assuming the worst input circuit, so that, although we still get a nominal valve magnification of 14.2, we have had to secure stability by the very inefficient method of reducing a magnification which already existed before applying the valve. The answer is, however, only partial, as it is not necessary in practice to keep to equal power factors for both input and output circuits.

In Dr. Beatty's article on screen-grid valves with tuned anodes (*E.W. & W.E* p. 619, Vol. IV., 1927), the results quoted appear to be rather more favourable than would appear from the present reasoning, but it may be shown that in Dr. Beatty's worst cases the value of G is 0.312, and this value is too near to instability to allow of the wide range of condenser swing which is necessary when the receiver is intended to be used over a wide band of frequencies. If it is considered profitable to work nearer instability the H.F. transformer may be readily adapted for this purpose by adopting variable coupling. In this case our simple theory which assumes perfect coupling is not applicable, but the theory in the appendix shows that the method is quite feasible. In the case of tuned anodes the same effect

can be attained by a variable inductance in series with the primary, but this, as well as the case of tapped anodes, is really converting the tuned anode to a H.F. transformer.

Unequal Power Factors.

The theory assuming unequal power factors may be developed on lines similar to those given above. The results only will be stated. Let ψ_1 and ψ_2 be the power factors of the two circuits and let

$$\psi_e^2 = \tfrac{1}{2}\sqrt{\psi_1 \psi_2}\,(\psi_1 + \psi_2) \quad .. \quad .. \quad (22)$$

TABLE I.

MAGNIFICATIONS WITH TUNED ANODE CIRCUITS.

m_1.	m_2.	Overall Magnification.
13.4	13.4	190
20.0	9.63	204
50.0	5.76	305
100.0	4.46	473
200.0	3.48	734
400.0	2.74	1,160

Then to determine the stability condition we simply replace ψ in equations (15) and (16) by ψ_e.

The resonance magnification at the upper readings of the condensers is given by

$$v_0/v_1 = 14.2\, \psi_e/\psi_1 \psi_2 \quad .. \quad .. \quad (23)$$

the equation corresponding to (21) in the above theory.

In the case of anode tuning, where $r = 1$, we have $\psi_e = 0.0745$, so that for a given ψ_1 (22) determines ψ_2 and then (23) gives the magnification. This leads to Table I, where m_1 and m_2 are the circuit magnifications (reciprocals of power factors).

Table I clearly shows that the method of bringing about stability in tuned anode circuits by reducing both circuit magnifications simultaneously is the worst possible one and leads (in the present example) to a magnification of only 190, a value which could easily be attained by a very moderately efficient circuit. (See the author's examples of efficient coils, *Wireless World*, December 8th, 1926, where magnifications greater than 500 are quoted.)

To get the best out of a tuned anode circuit, one of the circuits should be chosen so as to have as high a circuit magnification as possible, and the necessary stability should be secured by applying damping in the other circuit.

It is also seen that it is impossible to assign a definite magnification to the combination valve plus tuned anode without specification of the nature of the input circuit. If the input circuit is sufficiently highly damped we can quote a very impressive figure for the valve magnification, but when this circuit is lightly damped, the possible valve magnification is very moderate because of the necessity for securing stability.

TABLE II.

MAGNIFICATIONS AND STABILITY RATIOS OF H.F. TRANSFORMERS.

m_1.	m_2 =	50	100	200	400	Tuned Anode.
50	Ratio	3.7	5.1	6.7	8.3	1
	Magnification	710	1,030	1,590	2,530	305
100	Ratio	5.1	7.4	10.2	13.3	1
	Magnification	1,030	1,420	1,850	3,170	473
200	Ratio	6.7	10.2	15.9	20.4	1
	Magnification	1,590	1,850	2,840	4,150	734
400	Ratio	8.3	13.3	20.4	31.8	1
	Magnification	2,530	3,170	4,150	5,680	1,160

It is clear from the symmetry of these equations that it is unnecessary to specify to which circuit ψ_1 and ψ_2 belong, so we will take ψ_1 as the smaller power factor.

Turning now to the H.F. transformer, we can choose ψ_1 and ψ_2 without regard to stability. This choice determines the effective power factor ψ_e and then the correct

transformer ratio follows from $r\psi_e = 0.0745$, while (23) determines the overall magnification. This leads to Table II in which the upper figure in each entry gives the correct transformer ratio and the lower figure the overall magnification.

The last column gives the overall magnification with the tuned anode when the input power factor is that of the first column and is inserted for ready comparison of the two methods. It is seen that in all cases the H.F. transformer shows considerable superiority.

Stabilisation by Capacity.

Another method of bringing about stabilisation is to work with condensers of larger capacity. Still, assuming equal condensers, we arrive at the formula $C_0\psi = 2.24$ for the stabilising capacity in $\mu\mu$F., and the magnification is $14.2/\psi$, exactly as when stabilisation is brought about by alteration of transformer ratio. There are, however, disadvantages associated with too large a capacity in the input circuit in that the pick-up E.M.F. is apt to be reduced when large capacities and small inductances are used. This is clear from equation (7) in the case where the input circuit is a frame aerial. We could also adopt different capacities in the two-tuned circuits. The theory then shows that some gain in magnification would result in the tuned anode circuits, but the input capacity would have to be considerable before the magnification reached that of the H.F. transformer, and as this would mean lack of standardisation in the condenser system, the adoption of different capacities is hardly to be recommended. On the whole it would appear that condensers having a range of 30–300 $\mu\mu$F., are about the best to use, as these condensers would override the effects of stray capacity and at the same time be sufficiently small to enable many turns to be used in the coils of the input circuit so as to secure a reasonable pick up E.M.F.

General Conclusions.

It has been shown that when a screen-grid valve is used between two tuned circuits, the residual capacity between grid and plate is the governing factor in the design of these circuits and that, apart from neutrodyning, the best way of securing stability without undue loss of efficiency is by using a radio-frequency transformer in which the primary turns are reduced until the requisite stability attained. The examples chosen to illustrate is the sort of efficiency to be expected are all based on a grid-plate capacity of 0.1 $\mu\mu$F., but it is quite possible that a good commercial screened grid valve will give magnifications twice those quoted in the examples. If this is so then a screen-grid valve should give results comparable with those from a neutrodyned triode without having recourse to the complications of neutrodyned circuits.

Although we have treated only the band 200 to 600 metres, the same principles apply to other bands and the theory shows that the transformer ratio required will vary inversely as the square root of the frequency of instability, while the expected magnification will vary in like manner.

Multi-stage amplification need not be treated in detail as the procedure indicated for one stage should also be applicable for many stages, stability being attained by reducing the primary turns of the intervalve transformers.

It would seem to the writer, however, that it would be preferable in multi-stage systems to interleave transformer coupling with resistance capacity coupling so as to reduce the possibility of instability owing to capacity coupling between tuned circuits.

Appendix.

Case of imperfect coupling.

If an inductance l is placed in series with the primary of the transformer, then the effective anode admittance is $r^2\beta$ in series with the admittance $1/j\omega_0 l$. Calling this βa we have

$$\beta a = r^2\beta/(1 + j\omega_0 lr^2\beta)$$

and the plate voltage becomes

$$v_p = -\sigma_{pg}v_1(1 + j\omega_0 lr^2\beta)/j\omega_0 L\{r^2\beta^2 + a\sigma_{pg}(1 + j\omega_0 lr^2\beta)\}$$

The voltage across the secondary of the transformer is

$$v_0 = rv_p/(1 + j\omega_0 lr^2\beta)$$

so that the overall voltage magnification is

$$v_0/v_1 = -r\sigma_{pg}/j\omega_0 L\{r^2\beta^2 + a\sigma_{pg}(1 + j\omega_0 lr^2\beta)\} \quad .. \quad (1)$$

or using the G, y notation and putting $\mu = \omega_0{}^2 lCr^2\psi$

$$v_0/v_1 = -\sigma_{p0}/j\omega_0 Cr\psi^2$$
$$[(1 + jy)^2 + 2jG\{1 + j\mu(1 + jy)\}] \quad . \quad (2)$$

This equation replaces equation (13) of the text.

Critical stability occurs when the real and imaginary parts of the denominator of (2) vanish simultaneously and thus we find on elimination of y

$$G^2 = (1 - 2G\mu)(1 - G\mu)^2 \quad .. \quad (3)$$

as the condition of critical stability.

If μ is small this may be expressed as a eries giving G in terms of μ—viz.:

$$G = 1 - 2\mu + \tfrac{9}{2}\mu^2 - 11\mu^3 + \frac{227}{8}\mu^4 \quad .. \quad (4)$$

This gives a good approximation up to $\mu = 0.1$, in which case $G = 0.837$. If we use (4) in association with equation (12) of the text to determine the correct transformer ratio, we are led to smaller values of r for stable working, but so long as μ does not exceed 0.1 the diminution is not serious.

If we have two imperfectly coupled coils having mutual inductance M and coefficient of coupling k, the above theory applies if we replace r by L/M and l by $L(1 - k^2)/k^2r^2$, so that, since $\omega_0{}^2LC = 1$, $\mu = \psi(1 - k^2)/k^2$. It is seen that with efficient coils, k may be made quite small before μ becomes as high as 0.1.

We conclude that the theory is reasonably applicable even when the transformer coup ling is not perfect.

Measurements of the Grid-Anode Capacity of Screen-grid Valves.

By N. R. Bligh, B.Sc. (Eng.).

SUMMARY.—Measurements have been made of the grid-anode capacities of the screen-grid valves of the S625 and the S215 type. The average figure obtained for the S625 was 0.022 micromicrofarads and for the S215 0.014 micromicrofarads.

Method of Measurement.

THE measurements were made with the valve filaments cold, though when the electron current is flowing the capacities may be slightly different.

A high oscillatory potential was applied across the valve grid-anode capacity C_0 and a standard capacity C_s.

If V_t is the total applied volts and V_s is the voltage across C_s

$$\frac{V_s}{V_t} = \frac{C_0}{C_0 + C_s}$$

and

$$C_0 \doteqdot C_s\frac{V_s}{V_t}$$

since C_s is about 10^4 times C_0.

Apparatus.

It was considered that the valves would safely withstand a voltage of 600 volts, and using an anode voltage of 420 volts on a D.E.T.1 valve, and a low decrement circuit, a voltage of 700 volts at about 1 mega-cycle was easily obtained. The high potential was read on an electrostatic voltmeter and the low potential on a thermionic voltmeter calibrated at low frequencies.

This voltmeter consisted of a bombarded D.E.V. valve and the circuit used was as shown. The negative bias of 1.5 volts was found advisable, though the voltage to be measured was only 0.1 volt, since, for voltage lower than this, short-circuiting the grid resistance R indicated the presence of grid current by a deflection of the galvanometer G.

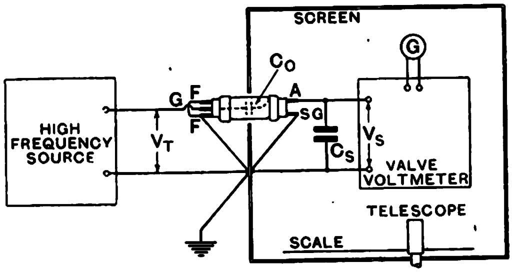
For these small voltages a reflecting galvanometer had to be used and this was used within the screening box.

The scale used was a transparent one reversed, since when viewed as a reflection in the galvanometer mirror, by means of a telescope, it becomes direct reading. The eyepiece of the telescope just projects through a close-fitting hole in the screening box. The galvanometer was brought to zero by varying the resistance R after the preliminary adjustments had been made, as the filament battery was the battery most likely to vary. To do this a close-fitting joint in the lid was made, as all the batteries and resistances are also in the box.

The S625 type of the Marconi Osram Valve Co. was measured first. It was placed in a long close-fitting brass tube in the side of the box.

The filament was earthed externally and the screen-grid internally. The high potential is applied between the control grid and the earthed screening box, the anode being in series with the standard capacity to the inside of the box.

It was decided to calibrate the thermionic



Arrangement of apparatus.

voltmeter before and after each test without opening the box. To do this a short piece of stiff wire was attached to the anode pin of the screened valve and hence electrically to the grid of the voltmeter valve. When the screen valve rotates in its tube the wire dips into a mercury pool, in a block of wax, and is connected by a lead to a terminal on the side of the box. During the high-frequency measurements this lead is earthed and the terminal covered by a metal cap.

Using these precautions and making the box of 25 S.W.G. tinned iron, no deflection of the galvanometer took place when the grid of the screened anode valve was earthed, though the electrostatic voltmeter reading 700 volts was directly beside the box. With the lid slightly raised there was no appreciable high-frequency pick-up, but stray low-frequency fields caused a slight deflection, since at low frequencies the grid circuit impedance is high.

Owing to a slight drift in the anode current, readings were taken at equal time intervals, but the deflections were very consistent and could be taken rapidly, agreeing to about 2 per cent.

For each valve four high-frequency measurements were taken. A series of low-frequency measurements were made for each reading, and the voltage to give the high-frequency deflection was obtained graphically. The value of the "standard" capacity includes the effective capacity of the thermionic voltmeter and of the leads to the anode of the screened valve and of this anode to earth, and since the screen-grid is earthed the capacity is quite appreciable. This total capacity was measured, therefore, with the valve in position and was of the order of 100 micromicrofarads. The shunting effect of the grid leak was therefore negligible. For the single-ended valves of the S215 type, of the M.O.V. Co., the screen-grid was earthed externally.

Measurements.

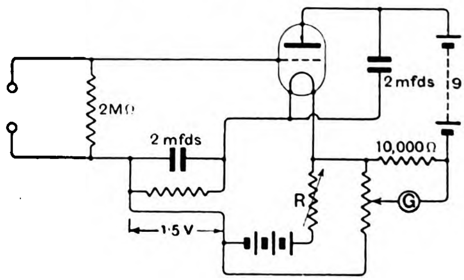
The values obtained were as follows :—

S625. C_0 — 0.021, 0.023, 0.021 and 0.022 micromicrofarads.

S215. C_0 — 0.016, 0.012, 0.015 and 0.014 micromicrofarads.

The mean valve for each set of four values was therefore, for the S625, 0.022 micromicrofarads and for the S215, 0.014 micromicrofarads, and the latter is slightly more variable.

Normally the screen-grid was at the centre of the tube, but measurements made with it just inside the end of the tube showed no change in capacity, and packing the tube tightly with lead foil also had no effect.



Valve Voltmeter circuit.

The values derived are of interest since they are of some assistance in circuit design, but care must be taken to reproduce the shielding conditions.

The author's thanks are due to Mr. A. C. Bartlett, of the Research Laboratories of the G.E.C., Wembley, for the suggestion of the method and advice in carrying it out, and to the above Company for permission to carry out the work in their laboratories.

On the Writing of Scientific Papers.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

I HAVE lately had occasion to prepare a *résumé* of the literature of a particular branch of the theory and technique of wireless communication. This involved the reading of a very large number of scientific papers and set me wondering why some of them should be so satisfying and easy to read and others of them so very much the reverse. It seemed a good opportunity to try to learn what things to aim at and what to avoid in the exposition of scientific and technical matters. Such observations as I was able to make on this subject I have ventured to set down here, not as a presumptuous offering of advice, but rather as an invitation to comment and suggestion. In doing so I shall at least have reinforced my own good intentions in this respect and may even succeed in interesting some of my fellow workers.

The general conclusion to which I was led is that the preparation and the writing of a paper on even the most severely scientific or technical of subjects is a work of art and should be conceived and executed in that spirit; that it should be judged by the same high standards as a work of art, and demands at least as high an endeavour. This will probably seem an extravagant idea to many, but there is indeed nothing extravagant about it. There is a closer kinship between science and art than is generally realised, though it has been clearly appreciated and as clearly expressed by men distinguished in either field, from Leonardo da Vinci, the great artist-scientist, onwards to, say, Henri Poincaré the mathematician, who has explicitly formulated the æsthetic basis of science in the following words. " The scientist does not study nature because it is useful to do so. He studies it because he takes pleasure in it, and he takes pleasure in it because it is beautiful. . . . I am not speaking of that beauty which strikes the senses, of the beauty of qualities and appearances. I am far from despising this, but it has nothing to do with science. What I mean is that more ordered beauty which comes from the harmonious order of parts, and which a pure intelligence can grasp." And again, suggesting a fundamentally æsthetic basis even for that which is usually considered the most purely rational of sciences, " Briefly stated, the sentiment of mathematical elegance is nothing but the satisfaction due to some conformity between the solution we wish to discover and the necessities of our minds, and it is on account of this very conformity that the solution can be an instrument for us."

This æsthetic element is not confined to the intellectual apparatus of science. It can, and should, find expression in all forms of scientific activity—in the devising of experiments, and the designing of apparatus with which to carry them out; in the analysis of data so obtained, and finally in the exposition of the matter for the benefit of others through the medium of the printed word. In all of these there is scope for that perfect adaptation of means to an end, that ordered harmony of parts and economy of effort that finds an immediate response in the æsthetic part of consciousness. I mean the kind of thing that will on occasion provoke the pleased exclamation " That's very neat," even from one who has no interest at all in the immediate object of the work.

This æsthetic element in science is a tempting field for speculation, and there is a great deal more I would like to say about it; but that would take me rather far from the immediate subject of this essay, which is the technique of the art of applied science, more especially in relation to the writing of scientific papers.

That technique arises naturally from the character of the scientific method. One of the principal characteristics of the scientific method, as also indeed of all forms of art, is economy. To quote once more from Poincaré: " . . . economy of thought, that economy of effort which, according to Mach, is the constant tendency of science, is a source of beauty as well as a practical advantage."

The pursuit of economy will impose certain definite rules. One of the most important can be worded thus. In the analysis or the experimental investigation of any given problem, endeavour to isolate the essential variables.

Two simple examples will perhaps help to

make this clear. The anode current in a triode valve is a function of the anode and grid voltages. Representing it by

$$i_a = f(v_a, v_g)$$

it appears that a whole family of curves will be required for a satisfactory delineation of the characteristics of the valve for the range of practical values of v_a and v_g; but a theoretical analysis will show that within certain limits of approximation the anode current is the same for any combination of anode and grid voltages which gives the same value to $(v_a + \mu v_g)$ where μ is a constant number. Here then, is an immediate economy. Putting

$$v_a + \mu v_g = V$$

then $$i_a = f(V).$$

Instead of two variables, the single variable V need only be considered, and, with sufficient accuracy for most practical purposes, the characteristics of the valve can be delineated by means of a single curve.

As another simple example, consider the voltage amplification given by an inductance L of resistance R in the anode circuit of a valve having the characteristics μ and R_a. It is easily shown that at an audible frequency $\omega/2\pi$ the voltage amplification is practically unaffected by the inter-electrode capacities and is given in vector form by

$$\frac{R + j\omega L}{R + j\omega L + R_a}\mu$$

This appears to be a function of five variables. The group ωL can, however, be treated as a single variable X, and any assigned value for this variable will then be applicable to any pair of values of ω and L having X as product. Thus a first simple economy gives the expression the form

$$\frac{R + jX}{R + jX + R_a}\mu$$

with four variables instead of five. A further inspection now shows that the essential variables of this problem are not R, X and R_a, but the ratio of R_a to $R + jX$. Putting $a + jb$ for this ratio, the expression becomes

$$\frac{\mu}{1 + a + jb}$$

The magnitude of which is

$$\frac{\mu}{\sqrt{(1 + a)^2 + b^2}}$$

The problem is now reduced to one of three variables only.

This economy of variables is obviously desirable for its own sake, but that is not the whole story. Observe that the elimination of each variable is accompanied by a gain in generalisation. For any assigned values of a and b, the above expression is applicable to *any* combination of anode circuit load and internal resistance which satisfies the equation

$$\frac{R_a}{R + jX} = a + jb.$$

Thus the idea of "essential variable" is closely connected with and leads naturally to the idea of generalisation, and generalisation is the very soul of science. It is in respect of this vitally important feature of generalisation that most of the papers I have read in preparing the *résumé* mentioned above are open to criticism. Paper after paper was found to contain nothing more than a record of particular measurements of particular cases, with little or no attempt to disengage the soul of the problem from its matrix of accidental circumstance. In many cases the paper demonstrated nothing more than the author's ability to work out a particular sum in arithmetic and get the correct answer. This achievement is no doubt a source of gratification to the individual concerned, but it is inadequate as a reward to the reader for devoting his attention to the performance.

In some cases the work has been so designed that it does not even contain the possibility of generalisation, suggesting too little thought at the commencement. In others one feels that the author has stopped thinking too soon at the end, for a potential generalisation is arrived at but remains unrevealed.

For a very good illustration of the latter kind I will refer to a paper on aerial couplings which was published some years ago in *E.W. & W.E.*, and lest it be thought that I am unfairly particularising an individual writer for my own base purposes, I would like to state that the paper in question is in my opinion, a very good one indeed. My

only criticism is that one step more would have made it even better. The paper is concerned with, amongst other matters, the receiving arrangement shown in Fig. 1a, represented for analysis by the equivalent circuit of Fig. 1b, where C_1 represents the effective aerial capacity, including the series condenser, R_1 the effective aerial resistance, and R_s the effective input shunt resistance of the receiver. It is shown that under suitable conditions V/E (R.M.S. values) reaches an optimum value given by

$$\frac{V}{E} = \frac{1}{2}\sqrt{\frac{R_s}{R_1 + R}}$$

and there the matter is left. This is certainly a useful and simple result, but it

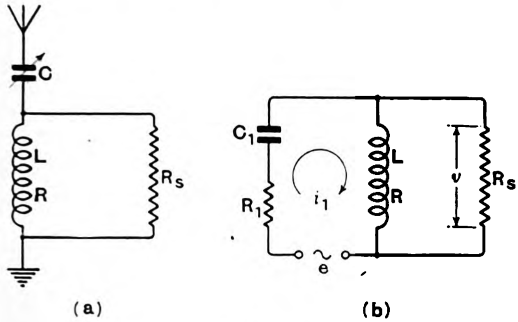


Fig. 1.

stops just short of an even more useful and interesting generalisation. Notice in the first place that a square root of the ratio of two resistances has no immediately obvious physical significance. This aspect of the matter is important and will be further considered. For the present it is enough to point out that this fact should in itself prompt further enquiry, and the squaring of both sides suggests itself as the next step, i.e.,

$$\frac{V^2}{E^2} = \frac{R_s}{4\,(R_1 + R)}$$

This can now be rearranged thus

$$\frac{V^2}{R_s} = \frac{E^2}{4\,(R_1 + R)}$$

Already, the significance of the result is becoming clearer, for the left-hand side is the power consumption in the receiver. This fact gives a clue to the significance of the right-hand side, which is discovered to be the power consumed in the aerial and tuning circuit when i_1 is in phase with e and the effective resistance is doubled by the load effect of the receiver. A generalisation is now clearly outlined. It is that with *any* single-circuit aerial tuning arrangement in which power is absorbed by the receiver an optimum condition can be established in which there is a balance of power between the receiving system and the remainder of the circuit.

This will of course need further analytical confirmation and experimental test. I had, as a matter of fact, already arrived at such a generalisation by a different route before reading the paper referred to, and a paper on the subject has been prepared for publication. I freely admit that but for this I might not have perceived the generalisation implicit in the above quoted formula, but I also submit that I would have been open to criticism in failing to do so.

It is obvious that generalisation is a very desirable feature in the theoretical or experimental investigation of a problem, and one might be tempted to pursue in all cases the highest attainable degree of generalisation, but some word of qualification is here necessary. Be it admitted that generalisation is the very soul of pure science, it must be remembered, nevertheless, that applied science has, so to speak, a body as well, and a treatment which is all generalisation may not be any more useful than a bricklayer who is all soul. There is, for example, a well-known book on vector analysis, one section of which ends with the words, " Thus . . . the whole of dynamics is included in the remarkable formula $\bar{\nabla}\ (L) = 0$." Here is, indeed, the very ecstasy of generalisation, but, to put it colloquially though quite accurately, it is, from a practical point of view, altogether too much of a good thing. The matter is not one in which it is easy to lay down a hard and fast rule, but I suggest the following. A generalised treatment of a practical problem is economic up to the point at which the labour required to isolate a particular case becomes equal to that required for the investigation of the particular case *ab initio*.

In the above example of the generalisation of a particular result, mention was made of

the physical interpretation of a certain mathematical formula, and it was shown that the mere rearrangement of the formula in such a way as to bring out its physical significance was sufficient to reveal the latent generalisation. The example leads naturally, therefore, to a further consideration of this matter of mathematical

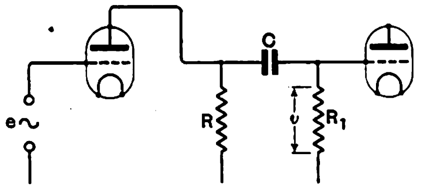


Fig. 2.

formulation, an element of great importance in the technique of the art of scientific exposition.

It has been said, somewhat cynically, that speech was given us to conceal our thoughts. Some writers on scientific subjects seem to think that mathematics was given them to conceal their physics. I would suggest that there is quite definitely a good and a bad mathematical style in the theoretical analysis of physical problems, and that a good style is one in which the mathematical formulation reveals, so to speak, the " physical anatomy " of the problem. An example will perhaps help to make this clear.

In *E.W. & W.E.* for April of 1927 there was published an article on resistance-capacity-coupled low-frequency amplifiers. It happens to be one that I wrote myself and I feel some diffidence in quoting from it on that account However, in spite of certain defects of which I am now uncomfortably conscious, I feel that I can at least claim that I endeavoured to keep the mathematical formulation of the matter clear in the above sense, and the paper contains a particularly good example of the advantages to be gained by so doing. The problem is that illustrated in Fig. 2, and it is a question of finding the ratio of V to E, assuming the valve to have the characteristics μ and R_a, at a low audible frequency $n/2\pi$, such that the inter-electrode capacities can be neglected. The circuit can be represented for analytical purposes as shown in Fig. 3. Treating the matter as an exercise in pure algebra, without reference to the physics of the problem, one would arrive at the following vector formula

$$\frac{V}{E}=\frac{jnCR_1(R+R_a)}{(R+R_a)^2+jnc\{R_1(R+R_a)^2+RR_a\}}\,\mu$$

which appears to be an arbitrary conglomeration of symbols quite devoid of physical significance. If, however, in carrying out the analysis, the symbols are organised as far as possible in natural physical groups, the result can be obtained in the form

$$\frac{V}{E}=\left(\frac{R_1}{R_1+\dot{Z}}\right)\left(\frac{R}{R+R_a}\right)\mu$$

where $$\dot{Z}=\frac{RR_a}{R+R_a}+\frac{1}{jnc}.$$

Here $\dot{Z}$ is obviously the impedance of the capacity C in series with the resistances R and R_a in parallel. The second and third factors in the expression for V/E represent the voltage amplification given by the valve in the absence of the coupling capacity and grid leak. The first factor, therefore, represents the effect of the coupling units on the resultant amplification. This is what I mean by a mathematical formulation which reveals the physical anatomy of the problem.

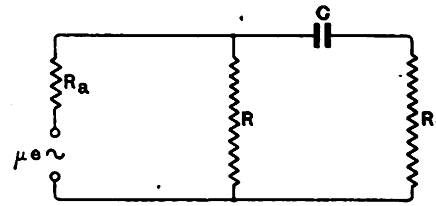


Fig. 3.

A further very important advantage of what I have called a good applied mathematical style is that it is far less liable to error than the pure algebraic style. Suppose, for example, that by some mistake in analysis the first factor had appeared in the form $\dot{Z}/(R_1+\dot{Z})$. A very little thought as to the physical significance of this would show that there was something wrong somewhere, whereas in the other formulation such a mistake might easily pass unnoticed.

The above reference to the physical anatomy of a problem introduces another important feature of technique, one which is, however, concerned with the design of experiment rather than with the exposition

of results. Æsop has neatly embodied the idea in his fable about breaking the bundle of sticks. In its present application the idea is that a problem should be resolved into its simplest factors. Suppose, for example, that it is desired to investigate frequency distortion in the reception of wireless telephony by means of a retroactive grid-circuit rectifying detector with one stage of transformer-coupled low-frequency amplification supplying a loud speaker. One might of course, induce a known modulated electromotive force into the tuned circuit and measure the sound intensity as a function of the modulation frequency, but the data so obtained would be practically useless for analytical or design purposes, for it would present the inextricably combined effects of no less than ten separate and distinct factors. These are :—

(*a*) the side-band cut-off effect of the input tuned circuit ;

(*b*) the inherent frequency-efficiency variation of the grid-circuit rectification process ;

(*c*) the effect of the load in the anode circuit of the detector valve on the input impedance of the latter, which input impedance will possibly modify (*b*) ;

(*d*) the frequency characteristics of the low-frequency transformer ;

(*e*) the effect of the detector valve on (*d*) ;

(*f*) the effect of the input impedance of the output valve on (*d*) ;

(*g*) the effect of the loud-speaker load on the input-impedance of the output valve, and thus on (*d*) ;

(*h*) the frequency variation of the impedance of the loud-speaker load ;

(*i*) the frequency variation of the electrical efficiency of the power-valve/loud-speaker combination ;

(*j*) the frequency variation of the acoustic efficiency of the loud speaker ;

A systematic analytical or experimental investigation of the problem requires the isolation and the separate investigation of each of these factors. This may appear laborious, but is in fact an economy of effort, for observe that, each factor being known, *any* combination of them is also known, whereas in default of such systematic investigation each particular combination would require investigation *de novo*, and the data obtained would not permit of further generalisation.

It might by some be thought unnecessary at this stage in our scientific development to preach so obvious a platitude, but in fact contemporary scientific literature contains a surprising amount of justification for so doing.

Finally, assuming that the work to be described has been well conceived and well executed, there remains the actual describing of it to be considered. Here the kinship with art, in this case the art of writing, is obvious ; but, of course, there are differences. The word "style" is applicable in both cases, but the criterion of criticism in scientific writing will be in some degree peculiar to itself. It is not a matter that lends itself to precise formulation, but there are certain general principles that will probably find acceptance, at least as counsels of perfection.

In the first place, it will probably be agreed that the feature which has importance above all these is clarity, and this should be sought not only in the choice of the individual word, but also, and more particularly, in the arrangement of the paper as a whole.

Some while ago, I happened to see a maker of clay statues at work. I noticed that he began by roughly fashioning a wire framework or skeleton which followed the main lines of the figure or group that was intended to be made. This was then clothed, still roughly, with clay, and finally, the actual modelling was done and superfluous material thumbed away. I felt that he was giving me a useful lesson in the art of writing scientific papers. Begin with the wire framework ; then, however complicated the theme, some degree of organic unity is assured. Bergson's essay on laughter, treated from a scientific point of view, is a beautiful example of the value of thus framing up the subject before clothing it in words. It is only fair to say that lack of preliminary design was not conspicuous as a defect in the papers I have had to read. In some even the authors had made things easy for the reader by a preliminary statement of exactly what questions they had set themselves and a final statement of exactly what answers

they had obtained. Such papers were rare, but very refreshing. On the other hand, there were papers of which the various parts seemed to have no more organic coherence than the apparently accidental circumstance of spatial proximity. These, fortunately, were also rare.

On the matter of actual wording and phrasing. I have no doubt that much could be said by a qualified person, which I do not claim to be. Here again, however, economy would seem to be a good guiding principle, leading to precision and aptness rather than abundance. As between hitting the bull's eye with a single well-aimed shot and blowing the target to pieces with a machine gun, there can be no doubt as to which is the more admirable performance.

Though I am here suggesting that clearness and economy are the principal desiderata of scientific literary style, I would not have it thought that the more purely literary graces are necessarily out of place in a scientific paper. Let those who have it in them to do so endow their scientific writings with all the beauty of English prose, so long as they preserve the precision and clearness which are the first essentials of scientific writing. After all there is no reason why a scientific paper should not be pleasant to read, in the ordinary æsthetic, as well as the intellectually æsthetic, sense. Up to the present, however, my experience is that such papers are non-existent in German, rare in English, and slightly less rare in French, but that of course may be an accidental consequence of my limited range of reading. Amongst those in English I might mention for instance those by Dr. W. F. C. Swann, in the Journal of the Franklin Institute. Here is one writer at least who can expound the weightiest of matters in a style that runs easily on light feet.

In conclusion, although I am not clear as to how far an essay on the writing of scientific papers is to be considered as a scientific paper, I feel I had better put myself on the safe side of my own criticisms by recapitulating the ideas which I hope to have demonstrated. I have sought to show that the application of the scientific method and the writing of scientific papers should be considered as a work of art, and that in the technique of that art the following are important elements :—

(1) The isolation of the essential variables of a problem both in analysis and in the design of experiments.

(2) The attainment of the highest economic degree of generalisation.

(3) The preservation of the "physical anatomy" of a problem in its mathematical formulation.

(4) The reduction of a problem to its simplest constituent elements for purposes of investigation.

(5) The arrangement of the written exposition in a manner appropriate to the organic unity of the problem considered.

(6) Precision and economy in the phrasing of the written exposition.

Push-Pull Amplification.

The Use of Resistance Capacity Coupling.

By F. Aughtie, M.Sc.

SUMMARY.—To obviate the need for a transformer, use is made of the phase reversal which takes place in a single resistance capacity coupled stage, to provide a grid feed for the second valve of the output pair.

A potentiometer adjustment enables the grid swings of the two output valves to be adjusted to give optimum output power, the correct setting being obtained very easily using only a milliammeter and a pair of phones.

THE arrangement of a pair of valves, (or banks of valves), working in opposite phase, commonly called "Push-pull," has not hitherto been extensively used for amplifiers designed for the highest quality, probably because the usual circuit requires the use of a transformer having a centre tap on the secondary. It is possible, however, to utilise the phase reversal given by a single resistance coupled stage to replace the transformer, enabling resistance coupling to be used throughout.

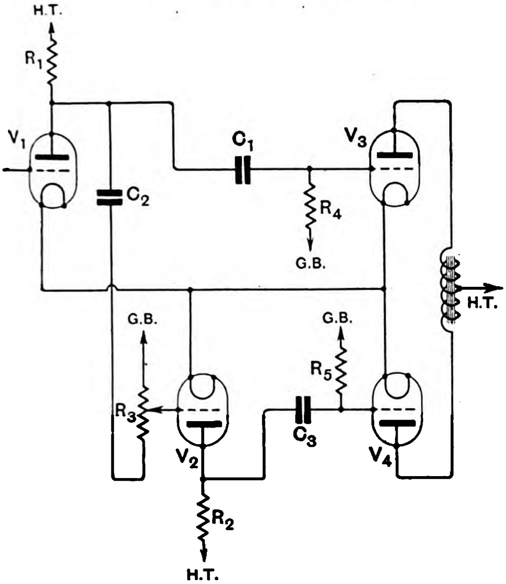


FIG. 1.—*The grid swing of the valve V_3 is reversed in phase by the valve V_2 and applied to the grid of V_4. The tapping on R_3 is adjusted so that the anode current variations of V_3 and V_4 are the same.*

In a single stage, comprising a valve and anode resistance, when the grid is made more positive, the feed current increases: this causes a larger drop of voltage in the coupling resistance, and hence the anode becomes less positive. The grid of the succeeding valve thus becomes more negative. If then the stage gain is made unity by any convenient means, we have a device which gives a phase reversal and which can be used to provide the grid swing for the second valve of the output pair. The stage gain is most conveniently reduced by feeding the input through a potentiometer, rather than by reducing the output, since the valve has then to deal with a smaller voltage swing.

Referring to Fig. 1, V_1 is the normal penultimate valve of the amplifier, its grid being fed in the usual way: it feeds one valve V_3 of the output pair through the condenser C_1, and also the grid of the phase reverser valve V_2 through the condenser C_2, and potentiometer R_3 which serves also as a grid leak. The grid of the second output valve V_4 is coupled to the anode of V_2 with the condenser C_3.

Alternatively, the feed for V_2 can be tapped off from the resistance R_1 as shown in Fig. 2: there is little to choose in practice between these two arrangements, as once the correct tapping has been found it remains fixed until one of the two output valves is changed.

Clearly the potentiometer ratio should be independent of frequency, and hence if the tapped grid leak arrangement is used, the leak should be of fairly low resistance so that the input capacity of V_2 causes no sensible alteration in the ratio over such frequency ranges as are used in practice. This effect is further minimised by using a valve having a low amplification factor for the phase reverser, not only because this reduces the step down ratio required in the potentiometer, but also because the input capacity of such a valve will be lower than

that of an otherwise similar valve having a higher amplification factor. In general, V_2 is most conveniently made of the same type as V_1, and since the output voltages are approximately the same, the coupling resistances can have the same value.

Due to the input capacity of the valve V_4, the reversal of phase given by V_2 will not be complete for the higher frequencies, but for such deviations as are likely to occur in practice, this results in a negligible loss, as may be seen by drawing the vector diagram. Fortunately, both this effect and the variation of stage gain with frequency are minimised by using a valve having a low amplification factor for V_2*.

So far, it has been assumed that the input swings to the two output valves are the same, and that a common value of grid bias is used. It has been shown by Denman (*E.W. & W.E.*, Vol. IV, page 669, and Vol. V, page 42) that when two slightly dissimilar valves are operated in parallel, a considerable increase of maximum (distortionless) output power can be obtained by supplying the valves with separate grid bias and input swings.

Unless separate output transformers are used (and the slight additional gain resulting from their use is insufficient to warrant this) the optimum adjustment is such as results in equal H.T. feed currents to the two valves, and equal changes of anode current when operating into their normal load.

The first condition, that of equal feed currents, is readily obtained with a milliammeter, since it is obvious that separate grid bias can be applied to the two output valves through the two grid leaks R_4 and R_5. This adjustment has the further advantage of completely removing any polarisation from the core of the output choke (or transformer).

The second condition, that of equal alternating output currents from the two valves, is even more readily obtained. Obviously, the H.T. feed is the sum of the two anode currents and (since the two valves are operating in opposite phase) when the grid swings are such as give rise to equal current changes, there will be no component of the signal frequency in the H.T. feed. Thus, if instead of adjusting the potentiometer to give equal grid swings, it is adjusted so that when the valves are operating into their normal load the H.T. feed is free from any signal component, the output valves will then be working to their best advantage.

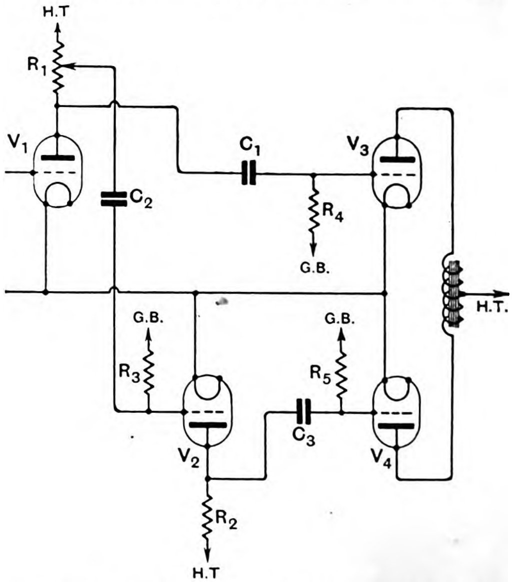


FIG. 2.—*To obviate the use of a large condenser for C_2 caused by the need for a low value of R_3 when the circuit of Fig. 1 is used, the grid swing for V_2 may be tapped off from the coupling resistance R_1. It is not necessary to alter the position of the tapping after initial adjustment.*

In practice, the setting of the potentiometer is altered until there is no sound, or a minimum sound, in a pair of phones connected in the H.T. lead to the last stage when there is a signal input to the grid of valve V_1. Naturally the feed current should be kept out of the phones by the use of a suitable choke and condenser filter.

This setting also results in there being a minimum of back coupling to earlier stages due to battery resistance.

The adjustment is most conveniently done with a single frequency input, since if the output valves are dissimilar, the setting will depend upon the output load, and this will, in general, vary with frequency. Thus it is not possible to obtain complete silence in the phones if the input to the valve V_1 is not of a single frequency.

A second factor which prevents a complete extinction is the departure from complete phase reversal at high frequencies due to

* See Hartshorn, "Inter-electrode Capacities and Resistance Amplification," *E.W.*, Vol. V, p. 419.

the input capacities to which reference has already been made, thus the adjustment is most conveniently made at a medium frequency where this effect is small.

As compared with normal parallel operation of two valves, the arrangement described has the following advantages:—

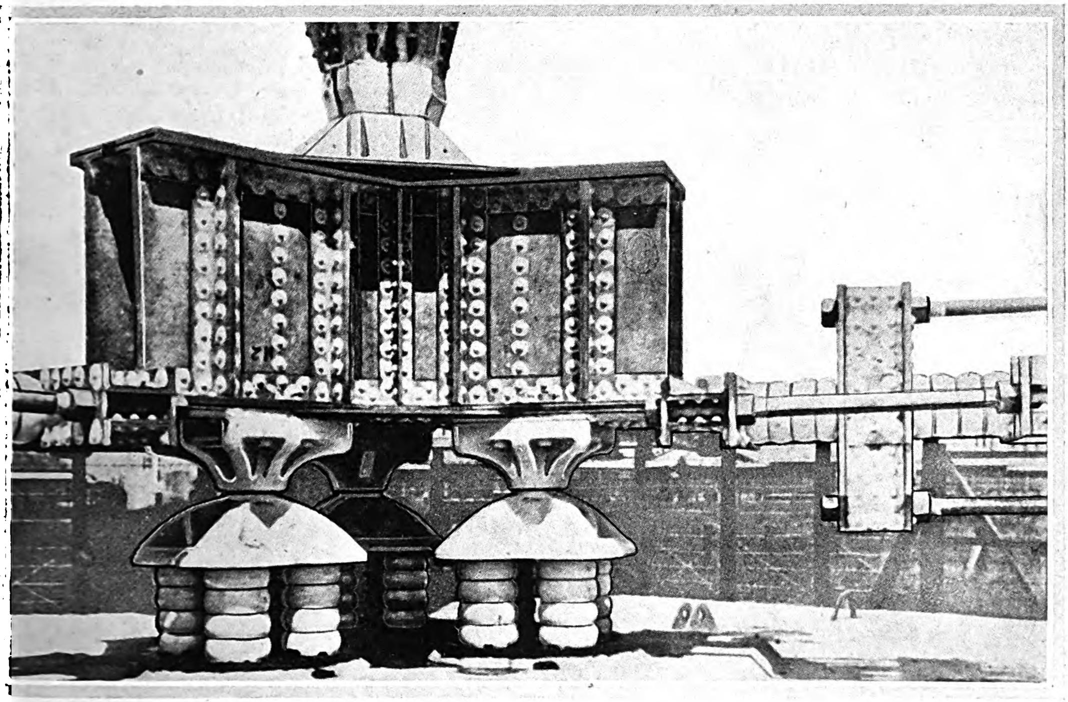
(1) There is no polarisation of the output choke, hence it can be made smaller.

(2) If the output valves are slightly dissimilar the output power may be increased by as much as 200 per cent.,* while at the same time the back coupling due to battery resistance is greatly reduced.

It may be noted as a matter of interest, that by inserting a choke in the H.T. feed to the valves the input swings can be adjusted so that both valves are working over the whole of the straight portion of their characteristics (the grid remaining always negative), and hence the output power will be the sum of the two operating singly. This would, however, give a gain altogether incommensurate with the additional complication.

* See Denman, *loc. cit.*

Nagoya Wireless Station.



The photograph reproduced here shows interesting details in the construction of the base of one of the masts of the Nagoya wireless station, which was built by the Telefunken Company for the Japanese Wireless Telegraph Company in Tokyo.

The special construction of the mast bases is made necessary in order to suit the peculiar conditions in Japan, where there is the ever-present danger of earthquakes, making it essential that, whilst maintaining proper insulation, the mast should have a certain freedom of movement within limits in the event of earthquake shocks. The station has eight masts, each 250 metres high, and is operated by a high-frequency alternator of 650 kW. From the point of view of power it is claimed that this station is now one of the largest in the world.

The Problem of "Turn-over."

By M. Reed, M.Sc., A.C.G.I., D.I.C.

It is found that under certain conditions the value of the current obtained in the plate circuit of a rectifying tube, for a given A.C. input, is not the same if the connections to the input of the rectifier are reversed. The ratio of the two values of the plate current is known as the "turn-over," and this article considers the conditions under which it is obtained.

The results obtained are applied to the case of the ordinary valve-voltmeter and to the valve-voltmeter which uses the "slide-back" principle.

Consider an ordinary rectifier and assume that the bias applied to its grid has a value a.

Since the output from an oscillator (or any similar system) is generally applied to a rectifier through a transformer, therefore the mean value of the oscillator voltage wave must be zero. It can therefore be represented by:

$$V_0 = V_1 \sin \omega t + V_2 \sin (2\omega t + \theta_2) + \ldots V_n \sin (n\omega t + \theta_n) = \phi(t).$$

The voltage applied to the grid of the rectifier is therefore given by:

$$v_g = a + \phi(t).$$

The equation of the rectifier characteristic can be represented by:

$$i_a = f(v_g).$$

Hence the plate current at any instant is given by:

$$i_t = f[a + \phi(t)].$$

This expression can be expanded by Taylor's Theorem and we have:

$$i_t = f(a) + \phi(t) \cdot f'(a) + \frac{[\phi(t)]^2}{\underline{|2}} f''(a) + \ldots \frac{[\phi(t)]^n}{\underline{|n}} f^n(a) \quad .. \quad (1)$$

where $f^n(a)$ denotes the nth derivative of $f(a)$.

The mean rectified plate current is given by:

$$I_+ = \frac{\omega}{2\pi}\int_0^{2\pi/\omega} i_t dt.$$

$$= f(a) + a_1 f'(a) + \frac{a_2}{\underline{|2}} f''(a) + \ldots \frac{a_n}{\underline{|n}} f^n(a) \quad .. \quad (2)$$

where

$$a_n = \frac{\omega}{2\pi}\int_0^{2\pi/\omega} [V_1 \sin \omega t + V_2 \sin (2\omega t + \theta_2) + \ldots V_n \sin (n\omega t + \theta_n)]^n dt \quad .. \quad (3)$$

If the connections from the oscillator to the rectifier are now reversed, the voltage applied to the grid will be given by:

$$v'_g = a - \phi(t)$$

Hence the mean rectified plate current will now be given by:

$$I_- = f(a) - a_1 f'(a) + \frac{a_2}{\underline{|2}} f''(a) + \ldots . (-)^n \frac{a_n}{\underline{|n}} f^n(a) \quad .. \quad (4)$$

The difference between the mean rectified current is therefore given by:

$$I_0 = I_+ - I_-$$

$$= 2\left[a_1 f'(a) + \frac{a_3}{\underline{|3}} f'''(a) + \frac{a_5}{\underline{|5}} f^v(a) + \ldots \frac{a_{2r+1}}{\underline{|2r+1}} f^r(a) + \ldots\right] \quad .. \quad (5)$$

We shall now evaluate a_1, a_2, and a_3. These can be obtained from equation (3) by putting $n = 1$, 2, and 3, respectively.

$$a_1 = \frac{\omega}{2\pi}\int_0^{2\pi/\omega} [V_1 \sin \omega t + V_2 \sin(2\omega t + \theta_2) + \ldots V_n \sin (n\omega t + \theta_n)] dt$$

$$= \frac{\omega}{2\pi}\int_0^{2\pi/\omega} V_1 \sin \omega t + \frac{\omega}{2\pi}\int_0^{2\pi/\omega} V_2 \sin (2\omega t + \theta_2) + \ldots .$$

$$= 0 \quad . \quad .. \quad .. \quad .. \quad .. \quad (6)$$

$$a_2 = \frac{\omega}{2\pi}\int_0^{2\pi/\omega} V_1 [\sin \omega t + V_2 \sin(2\omega t + \theta_2) + \ldots V_n \sin (n\omega t + \theta_n)]^2 dt$$

$$= \frac{\omega}{2\pi}\left[\int_0^{2\pi/\omega} V_1^2 \sin^2 \omega t \,.\, dt + \int_0^{2\pi} V_2^2 \sin^2 (2\omega t + \theta_2)\, dt + \ldots\right] + 2\,.\,\frac{\omega}{2\pi}\left[\int_0^{2\pi/\omega} V_1 V_2 \sin \omega t \,.\, \sin (2\omega t + \theta_2)\, dt + \ldots\right]$$

$$= \tfrac{1}{2}[V_1^2 + V_2^2 + \ldots V_n^2] \quad \ldots \quad \ldots \quad (7)$$

$$a_3 = \frac{\omega}{2\pi}\int_0^{2\pi/\omega}\Big[V_1 \sin \omega t + V_2 \sin (2\omega t + \theta_2) + \ldots V_n \sin (n\omega t + \theta_n)\Big]^3 dt$$

$$= \frac{\omega}{2\pi}\left[\int_0^{2\pi/\omega} V_1^3 \sin^3 \omega t\, dt + \int_0^{2\pi/\omega} V_2^3 \sin^3 (2\omega t + \theta_2)\, dt + \ldots\right]$$

$$+ \frac{3\omega}{2\pi}\left[\int_0^{2\pi/\omega} V_1^2\, V_2 \sin \omega t \,.\, \sin (2\omega t + \theta_2)\, dt + \ldots\right]$$

$$+ \frac{3\omega}{2\pi}\left[\int_0^{2\pi/\omega} V_2^2\, V_1 \sin^2 (2\omega t + \theta_2) \sin \omega t \,.\, dt + \ldots\right]$$

$$+ \ldots\ldots\ldots\ldots\ldots$$

$$+ \frac{6\omega}{2\pi}\left[\int_0^{2\pi/\omega} V_1 V_2 V_3 \sin \omega t \,.\, \sin (2\omega t + \theta_2) \sin (3\omega t + \theta_3)\, dt + \ldots\right]$$

$$= \tfrac{3}{4}[- V_1^2\, V_2 \sin \theta_2 + V_2^2\, V_4 \sin (2\theta_2 - \theta_4) + V_3^2\, V_6 \sin (2\theta_3 - \theta_6) + \ldots]$$

$$= \tfrac{3}{4}\sum_{r=1}^{r=n/2} V_r^2\, V_{2r} \sin (2\theta_r - \theta_{2r}) \quad \ldots \quad (8)$$

In practice the derivates such as $f'''(a)$, etc., would be calculated from the equation of that portion of the rectifier characteristic which was being operated on. It can generally be assumed that this equation will not contain terms with powers higher than the third, and hence all derivates higher than the third will be zero. It will be shown later that the assumption that the equation for the characteristic does not contain appreciable terms with powers higher than the third is justified.

Hence making use of equations (6) and (8) and assuming that the equation for the rectifier characteristic does not contain powers higher than the third, equation (5) reduces to:

$$I_0 = \frac{2a_3}{\lfloor 3} f'''(a)$$

$$= \frac{f'''(a)}{4}.\sum_{r=1}^{r=n/2} V_r^2 V_{2r} \sin (2\theta_r - \theta_{2r}) \quad (9)$$

As an illustrative example consider a voltage wave of the form:

$$V = V_1 \sin \omega t + V_2 \sin (2\omega t + \phi_2) + V_3 \sin (3\omega t + \phi_3) + \ldots . V_6 \sin(6\,\omega t + \phi_6)$$

applied to a rectifier whose equation is:

$$i = A + Bv_g + Cv_g^2 + Dv_g^3 + Ev_g^4$$

$$\therefore \quad \frac{d^3 i}{dv_g^3} = 6D + 24Ev_g$$

$$\therefore \quad f'''(a) = 6D + 24Ea$$

Since there are only six harmonics, therefore $n = 6$ in equation (9).

Hence:

$$I_0 = \frac{f'''(a)}{4}\Big[V_1^2\, V_2 \sin (2\theta_1 - \theta_2) + V_2^2\, V_4 \sin (2\theta_2 - \theta_4) + V_3^2\, V_6 \sin (2\theta_3 - \theta_6)\Big]$$

Therefore

$$I_0 = \tfrac{3}{2}(D + 4Ea)\,[- V_1^2\, V_2 \sin \phi_2 + V_2^2\, V_4 \sin (2\phi_2 - \phi_4) + V_3^2\, V_6 \sin (2\phi_3 - \phi_6)]$$

Consideration of equation (9) will give the different factors which influence the value of I_0. They may be summarised as follows:

(1) The value of I_0 will be zero if the equation of the rectifier characteristic does not contain powers higher than the second. In this case the value of $f'''(a)$ will be zero.

(2) If over a certain range, the equation of the rectifier characteristic can be expressed by a cubic, then, if the input is kept constant and the valve is operating within this range, the value of I_0 will be independent of the value of a (*i.e.*, the grid bias). This is due to the fact that for a cubic the value of $f'''(a)$ will be a constant and independent of a, and hence from equation (9) the value of I_0 will remain constant.

(3) For a given value of $f'''(a)$ and for a given wave form, the value of I_0 will increase with increase of input. It can be seen, for example, that if there is only a second harmonic present, the value of I_0 will be

proportional to the cube of the input voltage.

(4) The value of I_0 will be zero if the voltage wave does not contain the appropriate harmonics. It is seen that the value of I_0 is dependent on the product of a given harmonic with a harmonic of twice its frequency. Hence, unless the voltage wave contains a harmonic of double the frequency of any given harmonic, that harmonic will not influence the value of I_0. For example, the fundamental V_1 requires a second harmonic to give the necessary product, and hence so long as the voltage wave contains a second harmonic there will be a value of I_0, providing the other conditions are satisfied. Similarly a third harmonic requires a sixth harmonic to give the necessary product, and so on. Thus it can be seen that the value of I_0 will be zero if there are only odd harmonics present in the voltage wave. Even harmonics, higher than the second, will only influence the value of I_0 if the appropriate harmonics of half or double frequency are also present.

(5) The value of I_0 will be zero if some of the harmonics are not out of phase with the fundamental. In this case θ_2, θ_3, etc., will be zero, and hence $\sin(2\theta_r - \theta_{2r})$ will be zero, thus giving a zero value for I_0. Also, the value of the phase angle of any given harmonic must not be equal to half the value of the phase angle of the appropriate double frequency harmonic. If the phase angles are so related then $2\theta_r - \theta_{2r} = 0$, and the two harmonics under consideration will not affect the value of I_0.

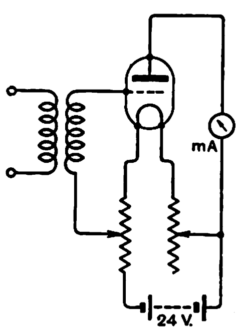


Fig. 1.—*Rectifier circuit.*

The above points can be summarised as follows: The difference between the two values of rectified plate current is due to the fact that the applied voltage contains certain out-of-phase harmonics, and that it is applied to a rectifier whose characteristic can be expressed by an equation which is at least a cubic over the working portion.

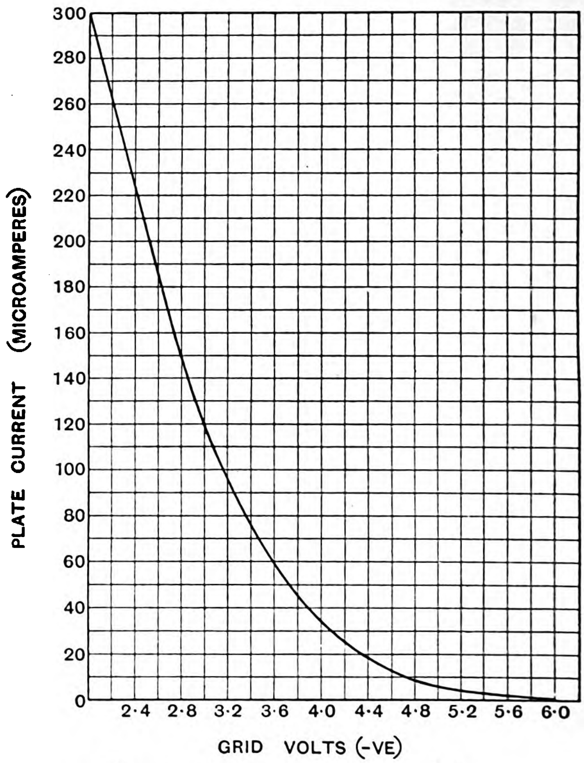


Fig. 2.—*Rectifier valve characteristic.*

Now "turn-over" has been defined as I_-/I_+ and it is therefore given by:

$$\text{T.O.} = I_-/I_+ = 1 - \frac{I_- - I_+}{I_+}$$
$$= 1 - I_0/I_+ \quad .. \quad (10)$$

Since the error introduced in a given measurement will depend not so much on the value of I_0 as on the relative values of I_0 and the nominal value of the plate current I_+, therefore the value of the "turn-over," and not the value of I_0 only, should be used as the basis of measurement. It follows that the error in a given measurement will be proportional to the amount by which the value of the "turn-over" differs from unity. With reference to the above, it should be pointed out that when making an experimental test, the key which reverses the output from the oscillator is labelled so that one position of the key is associated with I_+ and the other with I_-. The choice of these positions is quite arbitrary but it must be

adhered to throughout the test. Therefore in equation (10) it does not matter which we call I_+ or I_- so long as it is understood that one position of the reversing key will always give I_+ and the other I_-.

The above theory will now be applied to the case of the valve-voltmeter of the ordinary and of the "slide-back" type.

A rectifier of the form shown in Fig. 1 was fitted up and its characteristic obtained.

The non-linear part of the curve obtained is shown in Fig. 2, and by calculation its equation from $V_g = 2.8$ to $v_g = 5$ was found to be given very closely by:

$$L_a = 146 - 150\, v_g + 56.5\, v_g^2 - 7.9\, v_g^3$$

From $v_g = 5$ to $v_g = 6$, its equation was found to be:

$$L_a = 6 - 10\, v_g + 10\, v_g^2 - 9.3\, v_g^3 + 1.8\, v_g^4 + 2.2\, v_g^5$$

The curve between $v_g = 0$ and $v_g = 2.8$ is approximately a straight line.

For convenience the grid voltages have been plotted and inserted in the equations as if they were positive although actually negative bias was used.

From the equations it can be seen that when the valve is used as a rectifier, the major part of the operating portion of the characteristic can be represented by a cubic. Hence over this portion the value of I_0, for a given input, will be independent of the value of the grid bias.

Consider first the ordinary valve-voltmeter. In the case of this instrument the rectifier is calibrated with some fixed value of the grid bias; the unknown voltage is then applied and from the calibration curve the value of the applied voltage is obtained for the corresponding plate current. We are therefore interested in how the value of the "turn-over" varies for a given input with the value of the initial grid bias. The following test was therefore carried out. The input* to the rectifier was maintained constant, and for different values of the grid bias the values of the plate current with the connections to the rectifier normal and with these connections reversed were obtained. The measurements are given in Table I, and Fig. 3 shows a curve between "turn-over" and grid bias. From this curve it is seen that the amount by which the value of the "turn-over" differs from unity increases as the negative bias is increased. The reason for this is as follows:

TABLE I.

Initial Plate Current.	Grid Bias Volts.	I_- $\mu a.$	I_+ $\mu a.$	$I_0 = I_+ - I_-$ $\mu a.$	T.O. $= I_-/I_+$
5	−5.04	47	40	−7	1.175
10	−4.70	66.5	59	−7.5	1.125
15	−4.50	79.5	72	−7.5	1.102
20	−4.32	93	85.5	−7.5	1.086
30	−4.08	113.5	106	−7.5	1.070
40	−3.88	132	125	−7.0	1.055
50	−3.72	148.5	141.5	−7.0	1.050
60	−3.58	163	156	−7.0	1.045
70	−3.46	178	171	−7.0	1.040
80	−3.36	190	184	−6.0	1.032

A.C. input kept constant.

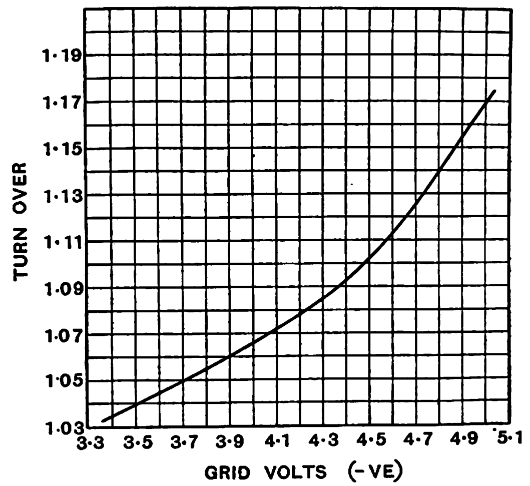


Fig. 3.—*Turn-over-grid bias curve with constant input.*

Since most of the measurements were made on, or very near to, the portion of the characteristic whose equation is a cubic, therefore the value of I_0 will not change very much with the value of the grid bias. The value of the nominal plate current (*i.e.*, I_+) will, however, decrease as the negative grid bias is increased, and hence the ratio I_0/I_+ will increase. Therefore the difference between the value of the "turn-over" and unity will decrease as the negative grid bias is reduced.

* The oscillator which gave this input was adjusted to give a bad wave-form.

· The fact that I_0 remains practically constant is borne out by column 5 of Table I.

In the case of the ordinary valve-voltmeter, therefore, the error due to "turn-over" will become less as the initial negative bias on the grid of the rectifier is reduced.

Consider now the case of the "slide-back" valve-voltmeter. In this case the plate current is set at some fixed value by means of the grid bias. The voltage to be measured is then applied and the grid bias is adjusted to give the same plate current.

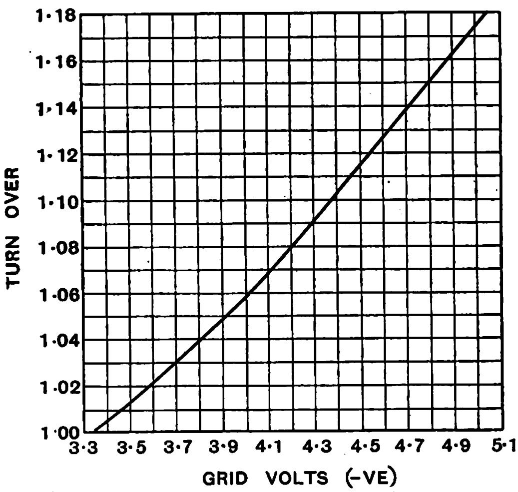


Fig. 4.—*Turn-over-grid bias curve with constant plate current.*

The difference between the two values of grid bias gives a measure of the applied voltage. In this case we are therefore interested in the change in "turn-over" with grid bias for a constant value of the plate current. The following test was therefore carried out. For different values of the grid bias the input was adjusted to give the same value of plate current with the connections from the oscillator to the rectifier normal. In each case the reading of the plate current with the connections reversed was recorded and the "turn-over" calculated. Fig. 4 shows the curve obtained between "turn-over" and grid bias. The "turn-over" is also a measure of I_0, since the nominal value of the plate current was made 100 micro-amps. It is seen that the curve of Fig. 4 is similar in shape to the curve of Fig. 3 in that the amount by which the value of the "turn-over" differs from unity decreases with decrease of negative grid bias. The shape of the curve of Fig. 4 can be accounted for as follows: Since the value of I_+ is kept constant, therefore we have from equation (10) that the value of the "turn-over" will be directly proportional to the value of I_0. Now as the negative bias is reduced, the initial plate current will increase and hence the value of the input will have to be reduced to obtain the same value for I_+. Also the rectifier is operating mainly over that portion of the characteristic which may be represented by a cubic, therefore the value of $f'''(a)$ will remain practically constant during the test. Hence it follows from equation (9) that the value of I_0 will decrease as the input to the rectifier is decreased, that is, as the negative bias applied to the grid is reduced. Therefore the amount by which the value of the "turn-over" differs from unity will become smaller as the negative bias applied to the grid is decreased. This type of valve-voltmeter is therefore similar to the ordinary valve-voltmeter in that the error due to "turn-over" becomes less as the negative bias on the grid is reduced.

A final test was carried out on the rectifier of Fig. 1. The grid bias was kept fixed at −4.32 volts and readings of "turn-over" for different values of the input were recorded. The measurements are given in

TABLE 2.

I_- Micro-amps.	I_+ Micro-amps.	$I_0 = I_+ - I_-$.	T.O. $= I_-/I_+$.
42	40	−2	1.05
53	50	−3	1.06
64.5	60	−4.5	1.07
87	80	−7.0	1.0875
109.5	100	−9.5	1.095
132	120	−12.0	1.10
154	140	−14.0	1.10
177	160	−17.0	1.106

· Grid bias kept constant at −4.32 volts.

Table II, and from these it is seen that the difference between the value of "turn-over" and unity increases slowly with increase of input. The reason for this is as follows:

Since the grid bias is kept constant therefore the value of $f'''(a)$ will remain constant, and hence from equation (9) the value of I_0 will increase as the input is increased. The value of I_+, however, will also increase with

input, and hence the ratio I_0/I_+ will only increase with input so long as the rate of increase of I_0 is greater than that of I_+.

The results of this test indicate how the valve will behave, with reference to "turn-over," when it is used as an ordinary rectifier.

Table 2 shows that for the inputs used during the test, the rate of increase of I_0 was greater than that of I_+, although the rate of increase of the latter seemed to increase more rapidly than that of the former as the input was increased.

Conclusions.

1. In both types of valve-voltmeters there will be an error due to "turn-over" if the applied voltage wave contains suitable harmonics and if the equation of the rectifier characteristic is at least a cubic.

2. The error due to "turn-over" will become less as the value of the negative grid bias on the rectifier is decreased.

3. To avoid error due to "turn-over" it would be necessary:

(*a*) To make the input free from harmonics, or

(*b*) To employ two valves to form a balanced rectifier. In this way full-wave rectification will be obtained and the value of the mean plate current will be independent of the connections from the oscillator to the rectifier.

4. The error due to "turn-over" can also be avoided:

(*a*) By employing a rectifier whose characteristic can be expressed by a quadratic over the operating portion, or

(*b*) By determining the value of the grid bias so that the operating point is in a region where the rectifier characteristic can be expressed by a quadratic, and arranging that the input to the rectifier is such that the grid swing does not go beyond this region. The valve-voltmeter can then be used in the manner indicated in Fig. 5.

The meter is calibrated by determining the attenuation required to give a fixed rectified plate current for known inputs to the terminals AB. The value of this rectified current is determined by taking into account the fact that the input to the rectifier must be such that the working portion of the characteristic can be expressed by a quadratic. The value of an unknown voltage can then be determined from the calibration curve from a knowledge of the attenuation required to give the fixed plate current with that voltage. In this method the input to the rectifier will be the same for all voltages applied to terminals AB and hence the same

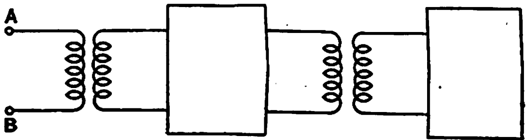


Fig. 5.—*Method of employing the valve voltmeter.*

portion of the rectifier characteristic will be used in all cases. This method has the additional advantage in that the value of the rectified current will be independent of the shape of the input wave and it will be directly proportional to square of the R.M.S. value of the input voltage. The calibration curve will therefore hold for all inputs. The reason for this can be seen from the following considerations. Since the working portion of the rectifier characteristic can be expressed by a quadratic, therefore we have from equations (2) and (4) that:

$$I_p = I_+ = I_- = f(a) + a_1 f'(a) + \frac{a_2}{\underline{|2}} f''(a)$$

Hence from equations (6) and (7) we have:

$$I_p = f(a) + \frac{f''(a)}{\underline{|2}} \cdot \frac{V_1^2 + V_2^2 + \ldots V_n^2}{2}$$

Now $f(a)$ is the value of the plate current due to the initial grid bias, and $f''(a)$ will be a constant for a quadratic, hence the plate current due to the input voltage is given by:

$$I_p = \text{constant} \times \frac{V_1^2 + V_2^2 + \ldots V_n^2}{2}$$

$$= \text{constant} \times V^2$$

where V is the R.M.S. value of the voltage applied to the rectifier. Therefore the rectified plate current is directly proportional to square of the R.M.S. value of the voltage applied to the terminals AB.

It is obvious from equation (3) that this would not be the case if the rectifier characteristic had an equation which contained powers higher than the second.

A Portable Radio Intensity-Measuring Apparatus for High Frequencies.

(Paper by Dr. J. Hollingworth, M.A., M.I.E.E., and Mr. R. Naismith, A.M.I.E.E., read before the Wireless Section, I.E.E., on 1st May, 1929).

ABSTRACT.

THE recent increase in the use and importance of high-frequency transmissions renders urgent the need of apparatus capable of measuring field strength in absolute units. The requirements of such apparatus are:—

(1) It must be easily portable.

(2) It should be capable of use both with telephones and galvanometers.

(3) Abnormal polarisation should not affect the accuracy with which readings can be obtained.

(4) Accuracy of observation should be high, even at the expense of sensitivity.

(5) The time taken to make an observation should be as short as possible.

(6) The effect on the electromagnetic field of the apparatus and of the antenna should be known and should preferably be negligible.

General Principles.

There are two fundamental problems: (*a*) The use of an aerial system of known constants. (*b*) The production of a very small E.M.F. of known value and its introduction into the receiving set.

Aerial.—In the author's apparatus the aerial is untuned, and its maximum height kept well below $\frac{1}{4}\lambda$. The use of an aerial permits a greater equivalent height to be used at these high frequencies than is possible with a coil, and its disconnection during calibration simplifies the problem of screening.

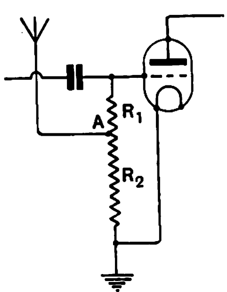


Fig. 1.—R_1 = 10,000 ohms, R_2 = 5 megohms.

The arrangement is shown in Fig. 1*, the aerial being separated from the grid by the high resistance R_1, which is thus in series with any parallel paths from the grid to earth. Special precautions are taken to keep the self-capacity of R_1 as low as possible so that the shunting effect produced by these paths on R_2 is kept small.

The aerial is led in through a $\frac{1}{4}$in. hole in the screen, thereby reducing the capacity to earth to a fraction of 1 $\mu\mu$F.

Receiver.—The first experiments were made with a commercial form of supersonic heterodyne receiver, but this was abandoned in favour of the circuit shown in Fig. 2. Wiring is kept as short and closely spaced as possible and a symmetrical layout is adopted. Toroidal inductances are used throughout, allowing the use of much smaller screening boxes, since the coil can be mounted quite close to the side of the box. The valve shown to the left-hand side effects retroactive tuning control. The aerial, as already shown in Fig. 1, is joined to an intermediate point in the grid leak of the detector valve, which works into a pentode. For aural working telephones are connected in this stage, but for observations these are replaced by a detector unit which rectifies the audiofrequency. The rectified current operates a microammeter of 24μA. full scale with a set of shunts. The heterodyne is coupled to the oscillatory circuit of the receiver by an untuned single-turn coil. By varying the position of this coil a great control of sensitivity can be obtained without any change in the tuning of any of the circuits. The effects of hand and body capacities are negligible.

Attenuator.—The two problems in any attenuator are (*a*) to produce a current of sufficient amplitude to be easily measurable; and (*b*) to cut this down by some known factor to give a value of E.M.F. of the order desired.

The first experiments were made with a condenser potential divider, but the results were unsatisfactory. The authors' arrangement is shown in Fig. 3, being in the form of a resistance potential divider.

The wavelength range of the complete apparatus is from 25 to 66 m., and the

* The authors' original figure numbers are adhered to throughout this abstract.

measurable intensity range is 10 to 10,000 μV. per metre.

Operation.—With the aerial-calibrate switch in the "aerial" position, the set is adjusted

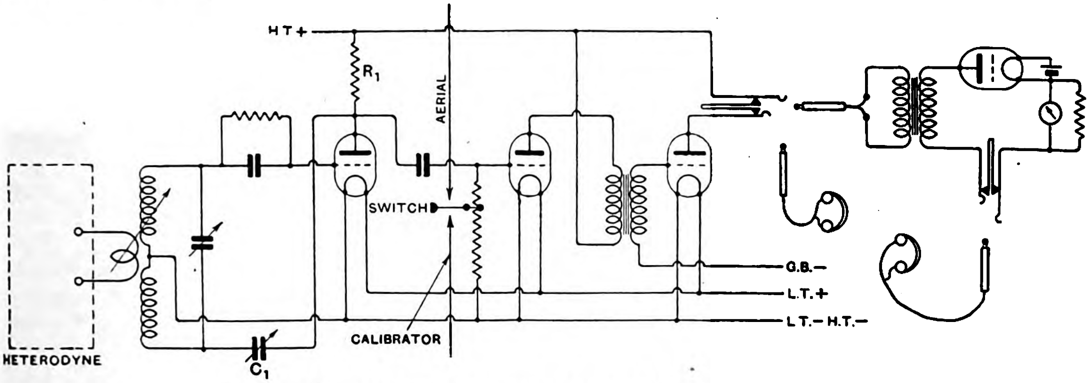


Fig. 2.—*Receiver for short-wave absolute intensity measurements.*

aurally. If the signal is of sufficient strength (*i.e.*, above 10 μV./m.) to deflect the output microammeter the detector unit is plugged in and the signal adjusted for reasonable output. The switch is then moved to "calibrate," the injection oscillator tuned to the signal frequency and attenuation applied to obtain the same deflection as from the signal.

Tests.

Various tests to verify the self-consistency of the apparatus are described and experimental results shown.

Relative Intensity Test.—A test for relative intensity was effected by a small 2-turn coil transmitter 200 m. from the receiver. This was orientated at different angles and the measured intensities give good agreement with the theoretical *sine* curve.

Test for Stray E.M.F.s.—A signal from the calibrator was steadily reduced by means of the attenuator. If stray E.M.F.s were present the output curve, if produced back, would cut the intensity axis at a positive point when the attenuation was infinity. The results show that the reverse is the case, due probably to non-linearity of the detector at low intensities.

Test of Aerial.—To verify aperiodicity the few lowest feet of the aerial were replaced by a piece of resistance wire of 500 ohms, the intensity was only reduced 30 per cent., showing that no resonance peak was involved.

Effective Height.—Measurements of effective height were made with an arrangement of 6 masts, each 5 m. high, round a circle of 8 m. diameter, with pulleys to allow the height and size of the top to be varied. Starting with the full height of 16 ft., the top was lowered in 2 ft. steps, while corresponding measurements of field strength were made 300 m. away. The results show that heights from about 4 ft. to 12 ft. are suitable for a standard transmission. Below

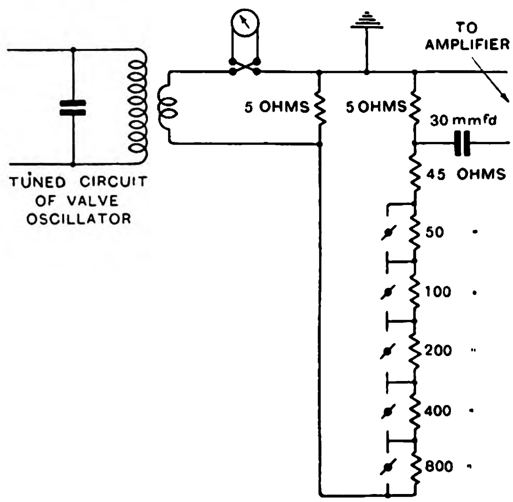


Fig. 3.—*Attenuator.*

4 ft. the small transmitter and containing hut probably exercise an effect; above 12 ft. it appears to be approaching the natural frequency of the aerial.

A further experiment tested the size of top required to give an effective height equal to actual height. Starting with a plain

vertical aerial 1.8 m. high, intensity measurements were made at 300 m. distance. Lengths of 2 ft. were added to the top in six radial directions and intensities measured, etc. The results show that effective height is equal to mechanical height when 8 to 10 ft. of radial top is in use. To check current distribution a second milliammeter was introduced at the centre of the vertical portion, and it was noted that its reading was the same as that at the base of the antenna when the radial wires were 8 to 10 ft. long.

Lastly, to test screened boxes, etc., the apparatus was set up in the open on a table 3 ft. above the ground, receiving from a small transmitter 200 m. away. A large screened box close to the receiver but resting on the ground gave considerable effect, and even when placed 1 m. away its effect was still noticeable. Ultimately, the receiver was placed in a pit so that no part of the apparatus was actually in the field to be measured. An aerial of just under 2 m. effective height was used, with the following results :—

Frequency, in Megacycles per sec.	Intensity.	
	Measured.	Calculated.
	$\mu V./m.$	$\mu V./m.$
10	650	675
7.5	520	510
6	340	335

No special significance is attached to the larger discrepancy for 10 megacycles, as this is within the accuracy claimed for this particular experiment.

After the reading of the paper the apparatus described was demonstrated in operation on signals and on local injection. A chart of the apparatus on a 24-hour record of signal was also displayed.

DISCUSSION.

Mr. E. B. Moullin, who opened the discussion referred first to the great difficulty of dealing with measurements at these frequencies. He was pleased to see the straightforward use of an aerial, and had always thought that an aerial was preferable to a coil for field-strength measurements. The solution shown was very interesting and useful. He also upheld the use of a resistance form of potential divider. Had the authors considered the use of a high-resistance wire in a concentric cable, of known or calculable capacity ? As regards the input/output curves shown by the authors, he suggested that the linearity of the detector at low intensities should be separately checked.

Mr. A. J. Gill referred first to the authors' requirement that the accuracy of the apparatus should be high. There was need for a tool for engineers' use where sensitivity was more important than extreme accuracy. Rapid variation of the signal itself made accuracy less important in commercial work, but ability to measure $\frac{1}{10}\mu V./m.$ was important. He considered the use of reaction very dangerous, and there was liability of it changing during measurements.

A field-strength-measuring set had been developed for the American Telegraph and Telephone Coy. in the Bell Laboratories and had been described by Friis and Bruce, in the proceedings of the Institute of Radio Engineers. The Post Office had constructed and used such sets in England. He showed a slide illustrating the principles of the apparatus and gave a brief outline of its operation. Slides were also shown of measurements made on a transmission from Dollis Hill at various points in and around London, the slides being in the form of intensity curves, and summarised in the form of a contour map.

Mr. J. F. Herd spoke of the need for information on the instrumental side of short-wave working. As regards the attenuator he suggested that information on the details of construction of the resistances for such high frequencies would be useful to other workers. He was surprised to learn that the authors had been criticised for their aerial arrangement. An aperiodic aerial with a resistance between it and the input grid had been in regular use for atmospheric observations for a long time. He did not agree with the authors in regarding the left-hand valve of Fig. 2 as the first valve of the system. The aerial terminal was the input and the valve shown in the left was an auxiliary. No doubt equal results could have been obtained with a conventional cascade, about the first valve of which there could be no doubt.

Dr. R. L. Smith-Rose suggested that, in the table at the end of the paper, the discrepancy shown for 10 megacycles was not greater than the probable error of calculating the attenuation between the local transmitter and receiver. He also criticised Fig. 2, and redrew the circuit showing the effective impedances from aerial input to earth. With the arrangement shown the experiment of replacing a portion of the aerial by a 500 ohms wire would not matter much.

Dr. Hollingworth briefly replied to several of the points raised in the discussion, and on the motion of the Chairman (Commander J. A. Slee, C.B.E.) the authors were cordially thanked for their paper.

This being the concluding meeting of the present session, the Chairman announced that Capt. C. E. Kennedy-Purvis, R.N., had been nominated as Chairman of the Wireless Section for the next session.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Transmitting Station actually sends out Waves of one Definite Frequency but of Varying Amplitude.

To the Editor, E.W. & W.E.

SIR,—In the discussion arising from the above subject, Mr. Aughtie brought up the apparent fallacy of envelope frequency alteration with carrier frequency harmonics if looked at from the spectrum basis, and Mr. Howe in the February issue has given a concise mathematical reply as to why

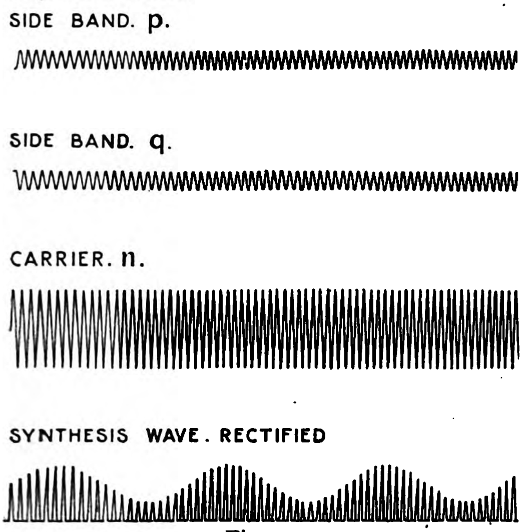


Fig. 1.

the envelope is not increased in pitch, and further that one can deal with it either from the spectrum basis or the single modulated carrier.

Mr. Howe says in his letter that it is difficult to form a clear mental picture as to why the envelope is not pitched higher when listening to the harmonic, and in this connection perhaps the attached curves with explanatory notes may be of interest, although I leave the exact interpretation of these curves to the reader.

Virtually the point in question is the following: If one rectifies a group of waves separately and then beats the result, is this the same thing as beating the waves first and rectifying the resultant wave? Mr. Aughtie says not, and suggests the case of a sine modulated wave, passed through a rectifier. Such a wave can be analysed into a carrier and two side bands, say, n, p, q, and if separate rectification of each is considered, the output will contain component frequencies of n, p, q, $2n$, $2p$, $2q$, etc. Mr. Aughtie then assumes that if one listens to the second harmonic of such a station we should hear the envelope pitched up an octave because one is dealing with the terms $2n$, $2p$ and $2q$.

No one denies the introduction of the multiple frequency terms due to rectifier distortion, but the fallacy of the argument at root is that one cannot assume the terms $2n$, $2p$ and $2q$ conveniently isolate themselves from all others to form the second harmonic modulated wave. Instead one must consider them in conjunction with other terms.

The writer came across this fallacy some time ago, and to see if additional light could be thrown upon the subject studied the effect with the aid of a mechanical synthesis machine on which a modulated wave can be built up automatically from a carrier and side bands.

The usual pictorial result obtained by the addition of carrier and side bands does not give us any information on the harmonic question, the curves of Fig. 1 being for a wave 50 per cent. modulated; the resultant being rectified.

But if the carrier and side band waves are each separately rectified, and then added, the resultant wave obtained is as shown in Fig. 2. Examination of this wave is of interest as the double frequency carrier can easily be picked out, and it will be seen that the envelope of this double frequency carrier is of the same, and not double, the frequency of the fundamental envelope.

The record also brings out a second point, observed by Mr. Howe, that the percentage modulation of the harmonic carrier is double that of the fundamental carrier. The latter in the example is

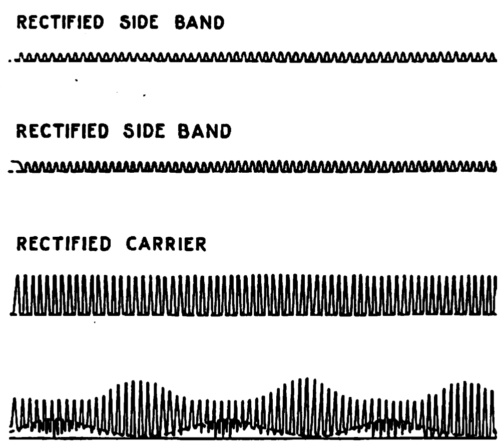


Fig. 2.

50 per cent., giving a 100 per cent. modulation of the second harmonic.

Fig. 3 shows the case of a wave modulated 100 per cent. obtained in the same manner, and here it is observed that the envelope of the second harmonic carrier is completely rectified.

Neither method of graphical representation of a modulated wave gives an accurate representation of the effect of rectification, but it would appear from the attached records that the second method of

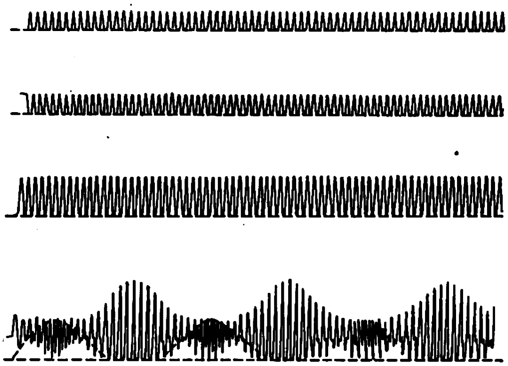


Fig. 3.

producing the result supplies information as to the behaviour of the modulation on the second harmonic.

A. W. LADNER.

Television.

To the Editor, E.W. & W.E.

SIR,—I note in the daily press and in several of your contemporaries that Denes von Mihaly is again coming into prominence in connection with far-reaching claims for his television apparatus.

In the issue of *E.W. & W.E.* for April, 1927, Mihaly attacked Mr. Baird with considerable assurance, pointing out that the disc method was hopelessly impracticable, and finishing up by asserting in the most insolent fashion that Mr Baird's statement that he used low frequency amplifiers to amplify the television signals at the Receiving Station was absurd, and that had Mr. Baird the knowledge that even an amateur possesses he would realise how ridiculous his statement was, thus insinuating that either Mr. Baird did not know what he was talking about, or that he was a pure mountebank. Following upon what appears to be Mr. Baird's usual practice, no reply whatsoever was given to this criticism, but time has shown how far Baird's statements were correct, and how absurd the criticism of Mihaly.

In his original apparatus Mihaly used a vibrating mirror of very small dimensions controlled by a stringed galvanometer. This device, as pointed out by Miss Everitt in the columns of *E.W. & W.E.*, was optically unsound, and there is no evidence that Mihaly was ever able to give anything in the nature of a public demonstration with it, although this did not prevent him from making claims of an extravagant nature.

At the German Radio Exhibition, however, Mihaly did demonstrate television of shadows, supplying, by the apparatus he used, the most convincing contraversion of his criticism of Baird, for he had discarded his mirror system, and was using an almost exact copy of the disc mechanism used by Baird.

The absurdity of his statement with regard to the impossibility of using a low frequency amplifier for television is made manifest by the fact that low frequency amplifiers are now universally used in all successful television demonstrations.

It is a well-known British trait to vaunt the foreigner and to accept any claims coming from abroad at the expense of the home worker, and I therefore feel the true facts of the case should be laid before you.

FULLARTON ROBERTSON.

Book Reviews.

THE PHYSICAL PRINCIPLES OF WIRELESS. By J. A. Ratcliffe, M.A. Pp. 104 + viii. 37 Figs. Pubd. by Methuen & Co. 2s. 6d.

This is one of Methuen's series of Monographs on Physical Subjects under the general Editorship of B. L. Worsnop, B.Sc., Ph.D., of King's College, Strand. The author, J. A. Ratcliffe, M.A., is a Fellow and Lecturer of Sidney Sussex College, Cambridge; he is known as a research worker on the characteristics of the waves employed in radio telegraphy and their reflection, refraction, and polarisation, and the little book is obviously written by a physicist with first-hand acquaintance with many of the problems of wireless. It is addressed both to physicists seeking information on the application of physical principles to wireless and to the practical man wishing to know more of the physical principles underlying the subject. Everything is necessarily treated very briefly, but the statement of the essential principles is very concise and clear. Except for a small printer's error on page 55, the only point we would criticise is the description on page 88 of the production of the oscillations of the Barkhauser and Kurz type; the explanation that they are caused by " the circulation of the electrons round the grid wires " might have been expressed a little more clearly. Such brief monographs written by those who not only have the scientific knowledge, but also possess the gift of imparting it, are very useful in these days of specialisation. We are pleased to note that Professor Appleton is writing one of the series on the Thermionic Valve.

STREIFZÜGE DURCH DIE EMPFANGSTECHNIK (selected chapters in the reception of broadcast signals). By Manfred von Ardenne. 99 pp., 106 Figs. Pub. by Rothgiesser & Diesing, Berlin, N.24. Bound in linen, M.3.50.

This book contains ten chapters, each devoted to the consideration of some subject of importance in the design and operation of wireless receiving equipment. Among the subjects dealt with are " The Frame as an Aerial," " Back Coupling," " Push-pull Experiments " and " Anode Bend or Grid Rectification ? ' 'These are all dealt with in a scientific but non-mathematical manner, with many practical hints and experimental results, obviously the result of much personal testing of the various circuits and devices. The book can be recommended to those with sufficient knowledge of the language. G. W. O. H.

Abstracts and References.

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PROPAGATION OF WAVES.

L'Absorption des Ondes Électromagnétiques au-dessus des Forêts (The Absorption of Electromagnetic Waves by Forests).—A. Nodon. (*L'Onde Élec.*, February, 1929, V. 8, pp. 85–86.)

After quoting Barfield's observations (Abstracts, 1928, V. 5: Rolf, p. 341; Barfield, p. 462) on the increased absorption of waves over wooded country as compared with other regions, and the increase of this absorption in summer over that obtaining in winter (30 per cent. increase), the writer mentions —as examples of the same effect—two French stations whose performance is handicapped by the presence of forests, and the well-known difficulties encountered in the forest-covered regions of Africa. He then suggests as an explanation the ionising effects of foliage: it is known that foliage produces an ionising radio-activity of the order of one-tenth that of uranium. Only a small part of this activity seems to be due to the potassium content; the total amount is appreciably increased at blossoming-time, and moreover increases with sunshine and diminishes at night. Thus the conductivity due to ionisation would explain the effects noted: it would be greater—in our parts of the world—in summer than in winter, since the leaves play an important part, while it would be more constant and more marked in the tropics, where the leaves rarely fall and where the sun's power is greater. The remedy appears to be to raise the stations to a height above the ionised layer of atmosphere above the forests.

The Equivalent Heights of the Atmospheric Ionised Regions in England and America. —E. V. Appleton. (*Nature*, 23rd March, 1929, V. 123, p. 445.)

Previous explorations with waves of medium length at night obtained evidence of the existence of at least two ionised regions in the upper atmosphere (Appleton, Abstracts, 1927, V. 4, p. 635). Now, the use of short waves has confirmed this for the daylight hours also: the lower region being penetrable by these (99.8 m.) waves on some days even at mid-day. On other days they are reflected at one moment and pass through at the next, owing to the inhomogeneity of the lower region. The mean equivalent heights of the two regions, from these latest tests, are 98 and 226 km. [For the medium waves, the heights indicated in the 1927 work were 90–130 and 250–350 km.]

The writer refers to the results of Breit, Tuve and Dahl in America (Abstracts, 1928, V. 5, p. 683) and points out that what they considered to be a doubly reflected ray from a layer at 105 km. is often (from their photographs) seen to be of greater intensity than the singly reflected ray; and that no triply reflected ray was found between the doubly and quadruply reflected ones. He suggests that these two difficulties would disappear if we adopt the double-layer hypothesis for the American as well as for the English observations: according to this, singly reflected rays were obtained at Washington from regions at heights of 105 km. and 225 km., and a doubly reflected ray was also obtained from the upper region.

An Investigation of Short Waves.—T. L. Eckersley. (*Electrician*, 19th April, 1929, V. 102, p. 468.)

Summary of the paper recently read before the I.E.E. Short Wave Scattering: Mutilation of Signals due to (*a*) "long" echo, (*b*) "quick" echo, (*c*) dispersion by passage through Heaviside layer—probably negligible on the short-wave band, (*d*) blurring, from multiple scattering, and (*e*) double or multiple signals (time interval of the order of 0.01 sec.), objectionable for picture transmission: Results of D.F. Interception of Short-wave Commercial Stations: Connection between Fading and Magnetic Storms: The Nature of Skip Effects—the Heaviside layer as a complex structure of scattering clouds: Revision of Author's Estimate of Effective (Daylight) Height from long-wave measurements—new estimate is about 80 km. for summer and 97–100 km. for winter: Lower Wave-length Limit for Night Transmission depends on season and time of night, late-night regions behaving very differently from early-night regions, thus confirming Appleton's results showing a progressive change in the layer during the hours of darkness; short-wave daylight limit appears to be close to 10 m., but sporadic long-distance transmissions have been observed on waves shorter than this.

Über die Ausbreitung der kurzen Wellen bei kleiner Leistung im 1,000 Kilometer-Bereich (Short-wave Low-power Communication for 1,000 Kilometer Range).—K. Krüger and H. Plendl. (*Zeitschr. f. Hochf. Tech.*, March, 1929, V. 33, pp. 85–92.)

Further developments in the work on short-wave aircraft communication referred to in Abstracts, 1928, V. 5, pp. 163 and 589. The immediate object of the present tests was to determine whether reliable communication could be counted on with low powers (2 watts in the aerial) for ranges of 600 or even 1,000 kilometres. The tests were divided into two parts: between two ground stations 500 km. apart, to find how signals varied according to time of day, etc.; and from aeroplane to ground station, to determine how signals varied with distance.

It was found that 2 watts from a quartz-controlled C.W. telegraph transmitter gave continuous communication over 600 km. by day; the best wave

was 50 m., and with this there were no zones of weakness. The height of the aeroplane had apparently no effect: signals were the same even if the machine had landed. Reception was even possible, at 500 km., when the aeroplane was housed in an iron-covered shed.

The average course of a test was as follows:—as the aeroplane, with its transmitter, started off from the receiving station, the strength of signals (as measured on a milliammeter) fell during the first 20 km. from 15 to 5 mA. and then remained constant over a long distance until a certain critical point was reached which varied according to the wavelength used. Beyond this critical distance, signal strength fell off rapidly, though communication still remained possible. For a 37.2 m. wave, this distance was about 800 m. (in March; in summer this wavelength gave a very inferior performance, zones of weak signals appearing at quite short distances); for 53 and 55 m. it was 400 m., while for the 50 m. wave it was 600 km.

Fading only became noticeable at ranges beyond the critical distance. Below about 38 m., zones of weakness frequently appeared: between 38 and 48 they only appeared occasionally, more markedly in summer than in winter. It is suggested (as a result of later tests) that if a vertical aerial or some aerial combination had been used at the receiver, these zones of weakness would have been less prominent: in the actual tests, di-pole aerials were used at transmitter and receiver. Communication on waves below 50 m. was subject to a sudden and marked interruption at night, presumably due to the migration of a zone of weakness, through changing height of the Heaviside layer.

The paper also describes tests where the reception was done in the aeroplane from the ground station. The previous results were duplicated so long as the aeroplane was on land, but when in the air the usual aeroplane interference made the 2-watt power insufficient on most occasions, though on one occasion this power gave satisfactory C.W. telegraphic communication up to 450 km. In other cases, 60 w. was used and was satisfactory up to 600 km.

Some Experiments in Short Distance Short-Wave Radio Transmission.—J. K. Clapp. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 479–493.)

Author's summary:—" Some experiments in short-wave radio transmission over a distance of 55 miles are described, the results of which are interpreted to indicate the presence of strong 'sky' waves, with 'ground' waves of negligible amplitude in comparison with the 'sky' waves as received. Upon decreasing the transmitter wavelength, at a given time of day, a minimum wavelength was reached below which no communication could be obtained; this wavelength is termed the 'cut-off' wavelength. The average value of the cut-off wavelength, for various times of day, is given for several different months. The minimum observed wavelength upon which communication was possible was 28 meters.

" A series of experiments in which an orientable half-wavelength antenna was employed served to indicate definitely an optimum position of the antenna for transmission over the 55 mile distance. The indicated transmission path left the transmitter at an angle of approximately 65 degrees to the horizontal. In long distance communication the position of the antenna was found to have no appreciable effect."

The range of wavelengths used was 25–80 m. The orientable aerial referred to consisted of 50 feet of copper tubing mounted on a lattice frame, carrying the transmitter at the mid-point. The centre of the frame was supported on a universal joint at the top of a 50 ft. pole set in a sandy beach. Incidentally, this beach was composed of fine sand, highly piezoelectric, showing strong resonance frequencies from 15,000 kc. to 3,000 kc. This would have to be taken into account in attempting to calculate the radiation characteristics.

The long distance tests, where apparently the random polarisation of the waves at the receiver, due to the characteristics of the medium of propagation, completely wiped out all effects due to the angle of the aerial itself, were mainly with England and Belgium.

In the short distance tests, twin transmitters and twin receivers were used, each receiver going to one telephone of a split head-set. Two wavelengths were thus tested simultaneously, both transmitters being keyed together. Adjusted to equality, the two lots of signals gave a resultant resembling that obtained with an ordinary single receiver, except that the signal appeared to change from one ear to the other, as the fading periods on the two wavelengths were not the same. No definite relationship between the fading periods on any two wavelengths was observed, even when the difference in wavelength was small.

Doppel- und Mehrfachzeichen bei Kurzwellen (Echoes, Single and Multiple, on Short Waves).—E. Quäck and H. Mögel. (*E.N.T.*, February, 1929, V. 6, pp. 45–74, with Supplement, pp. 74–79.)

A long paper, copiously illustrated by oscillograms, etc., based on recent observations at the Geltow receiving station on signals from Rio de Janeiro, Buenos Aires, New York, Mukden, Manila, Bandoeng, Siam, Cape Town and Nauen. Among the results may be mentioned the following:—(1) Echoes have been found for all waves from 12 to 45 m.; (2) the intervals measured between true signal and echo, or between successive echoes, are always longer than those calculated on the basis of the velocity of light in space and of the actual direct path-length round the earth, the observed intervals consistently suggesting a great circle distance of about 41,400 km.; (3) as opposed to the results of Taylor and Young, the intervals do not vary; (4) magnetic disturbances diminish the echoes, this effect being greater the stronger the disturbance and the nearer the angle between earth's field and direction of propagation approaches a right angle. The supplement deals with the short-time echoes (" nah-echos ") observed by Taylor and Young and Hoag and Andrew (January Abstracts, p. 38) examples of which have recently occurred at Geltow in recording (for check purposes) the signals from Nauen. Among others, an oscillogram is given showing how the record of the true signal (a

letter " v ") is blotted out by the short-time echo, while the round-the-world signal is perfect. Systematic tests were then carried out: dots, at half-second intervals, being transmitted. The records show that the short-time echoes vary greatly in form and in their intervals; generally, however, the average (group) interval is a whole multiple of the interval between true signal and first short-time echo. Thus one set of tests (using directional receiving aerials) shows a series of no less than 7 short-time echoes, corresponding to reflections at the following distances: 3150, 6300, 9300. . . . 23100 km. It may be concluded that they are due to multiple reflections between the earth and a layer about 1,500 km. above it (*cf.* Wagner, March Abstracts, p. 144.)

VARIATIONS IN SIGNAL STRENGTH FROM AUSTRALIA.—R. G. de Wardt. (*P.O. Elec. Eng. Journ.*, April, 1929, V. 22, pp. 52–58.)

A record from June, 1927, to November, 1928, of variations at Skegness of the Beam signals from Australia. Sunrise and sunset do not show any effect on the average strength when the service is worked on the " long " route (westward from England)—any possible effect being masked by the fact that the sun has risen in Australia before it has set in England on this route. On the " short " route, the Australian sunrise has a very marked effect on signal strength at certain periods of the year: the effect being noticeable half an hour to two hours before the sun actually rises, according to the month (maximum advance in winter). This effect (also apparent on the Indian service) appears to be due to the altitude of the sun and the formation of day conditions in the Heaviside layer before actual sunrise—this producing a diminution of signal strength, as the wave used is primarily a night wave.

Figures showing the attenuation produced under the differing daylight and seasonal conditions are given showing that, under similar seasonal conditions, daylight at the Australian end has a worse effect on signal strength than daylight at the English end. Unfortunately, similar figures for reception in Australia are not available; it is not, therefore, possible to say whether daylight at the transmitting end has a greater attenuating effect than at the receiving end, or whether the deciding factor is the difference in latitude.

ON THE DIFFERENCE OF EAST TO WEST AND WEST TO EAST RADIO TRANSMISSION PHENOMENA AT SUNRISE AND SUNSET.—T. Nakai. (*Res. Electrot. Lab.*, Tokyo, November, 1928, No. 241, 18 pp.)

In Japanese. Author's abstract:—The 24-hour change in the ionisation of the upper atmosphere by the ultra-violet ray emitted from the sun has been closely studied, and a conclusion arrived at that the Heaviside layer goes down far more rapidly after sunrise than it goes up after sunset.

Taking into consideration Kennelly's or Nagaoka's theory on sunrise and sunset effects, it may thus be said that no great difference between sunrise and sunset effects is to be found in the radio transmission from East to West, while sunrise effect is to be much larger than sunset effect in the transmission from West to East. This reasoning has been illustrated by the actual data of transmissions from Bolinas (22.9 kc., near San Francisco) to Isohama (near Tokyo) and from Haranomachi (19.8 kc., 150 km. North from Tokyo) to Marshall (near Bolinas).

ÜBER DIE ANWENDUNG DES EBERTSCHEN IONENZÄHLERS ZUR BESTIMMUNG DER ZAHL UND DER BEWEGLICHKEIT DER KLEINEN IONEN IN DER ATMOSPHÄRE (The Use of the Ebert Ion-counter for the Measurement of the Number and Mobility of the Small Ions in the Atmosphere).—W. J. Baranow and E. S. Stschepotjewa. (*Physik. Zeitschr.*, No. 21, 1928, V. 29, pp. 741–750.)

A method designed to avoid the usual errors. Mobility of the light ions is probably not less than 1.2 and 1.6 cm./sec.: volt/cm. for positive and negative ions respectively. There are great divergences, so that the mean mobility in no way expresses the mobility of certain groups. To obtain useful results the ions must be divided into several groups, and the average mobility determined for each group separately.

SUR L'IONISATION ATMOSPHÉRIQUE (Atmospheric Ionisation).—Ch. Maurain and E. Salles. (*Comptes Rendus*, 4th March, 1929, V. 188, pp. 723–725.)

A summary of measurements of large and small ions at Val-Joyeux and Paris, and a discussion on their meaning.

L'ÉCLIPSE DU SOLEIL DU 9 MAI 1929 (The Solar Eclipse of 9th May, 1929). (*L'Onde Élec.*, February, 1929, V. 8, pp. 80–84.)

The programme of the Baïkam (Indo-China) Expedition.

THE ANGULAR DISTRIBUTION OF INTENSITY OF RESONANCE RADIATION.—R. W. Gurney. (*Nature*, 23rd March, 1929, V. 123, p. 479.)

Summary of a Washington (Nat. Ac. Sci.) paper. The assumption of random distribution is suggested to be unwarranted. If the plane of polarisation of plane polarised light is rotated rapidly, consideration of the movement of the atomic oscillators shows that, though the intensity along the beam is unaltered, in other directions it is modified.

A GRAPHICAL THEORY OF TRAVELLING ELECTRIC WAVES BETWEEN PARALLEL CONDUCTORS.—N. Karapetoff. (*Journ. Am.I.E.E.*, February, 1929, V. 48, pp. 113–117.)

VARIATION OF CONDUCTIVITY OF THE UPPER ATMOSPHERE.—J. Egedal. (*Nature*, 27th April, 1929, V. 123, pp. 642–643.)

" Summarising, it may be said that the heights of the base of the aurora are able to give information on the tide of the upper atmosphere and thereby on the variation of the electric conductivity in the regions considered; further, that certain observed magnetic variations seem to confirm the result found. The existence of a resulting enormous variation [in latitude 45 deg. a variation of 25 per

cent. from the mean height may be expected] of the height of the conducting layer may be tested by means of radio waves."

Über die experimentelle Erforschbarkeit der höheren Schichten der Atmosphäre (On the Explorability of the Higher Layers of the Atmosphere).—H. Benndorf. (*Physik. Zeitschr.*, 1st March, 1929, pp. 97–115.)

A general survey. This, the first part, deals with the exploration by means of sound waves.

Die Schallausbreitung in der Atmosphäre bei künstlichen Sprengungen (Sound Propagation in the Atmosphere from Artificial Explosions).—O. Meisser. (*Physik. Zeitschr.*, 15th March, 1929, pp. 170–175.)

The Total Reflexion of Electric Waves at the Interface between Two Media.—H. M. Macdonald. (*Proc. Roy. Soc.*, 6th April, 1929, V. 123 A, pp. 391–400.)

A mathematical investigation of the transmission and reflexion of electric waves, when the surface separating the media is a sphere, and the source of the waves is a simple oscillator inside the sphere, whose axis passes through the centre of the sphere.

Signal Strength Measurements at Bangalore.—K. Sreenivasan. (*Electrotechnics*, Bangalore, March, 1929, pp. 199–200.)

The strength of 3 minute dashes from Rugby was measured at Bangalore at the same hours each day over two months. The effect of earthing the insulated masts at Rugby was noted; signal strength rose from less than 0.28 microvolt/metre per aerial ampere (all masts but one insulated) to 0.31 (two masts earthed), to 0.335 (three earthed) and to 0.386 (six earthed). Another result to which attention is directed, though the short duration of the test is recognised, was that transmission with the waves travelling all the way in darkness gave a signal about 35 per cent. stronger than the daylight transmission. The mean morning and evening strengths are respectively 270 and 200 microvolts per metre, with 800 amperes aerial current.

The Measurements of the Field Intensities of some High-Power Long-Distance Radio Stations. Part II.—Malabar, Palao and Rugby; Part III.—Kahuku, Pearl Harbour and Saigon. E. Yokoyama and T. Nakai. (*Res. Electrot. Lab.*, Tokyo, July and September, 1928, Nos. 233 and 238.)

A continuation of the work referred to in Abstracts, 1928, V. 5, p. 683.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

Wireless Telegraphy and Magnetic Storms.—H. B. Maris and E. O. Hulburt. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 494–500.)

Authors' Summary :—A recent theory of auroras and magnetic storms (Abstracts, 1929, V. 6, pp. 101, 147 and 265) attributes these phenomena to the action of a flash of ultraviolet light from the sun. The flash causes an unusual ionisation in the Kennelly-Heaviside layer. Therefore, it is only daylight wireless circuits which are, or may be, disturbed at the commencement of the magnetic storm, the night circuits remaining normal until dawn, when they may be disturbed ; the disturbance in the daytime circuits may persist after night-fall. This very simple theory is found to be borne out in a detailed discussion of the data of the short-wave (15 to 40 meters) circuits of the United States Navy during the magnetic storms of 28th May, 7th July, 18th October, and 24th October, 1928.

Weather and Wireless.—R. A. Watson Watt. (*Nature*, 30th March, 1929, V. 123, pp. 500–501.)

Summary of the Symons Memorial Lecture of the Royal Meteorological Society. Among the points made, the following, relating to atmospherics, may be mentioned :—The average atmospheric is a hundred thousand times as strong as a readable signal ; they have been known to disturb broadcast reception up to 4,000 miles from their place of origin. They originate in thunderstorms, and the predominant source of the world's supply of atmospherics at any moment usually lies in a land where it is summer afternoon. The average atmospheric received in England is of such strength as would be expected from a thunderstorm 2,000 miles away.

The lecture was illustrated by the reception, on the Fultograph system, of current weather maps and written forecasts, and by demonstrations of the author's cathode ray direction finder. It was mentioned that an experimental transmission from Daventry of daily weather charts is to begin shortly.

A fuller summary, with reproductions of the synoptic chart and forecast mentioned above, is given in the next issue (6th April), pp. 545–546; another (also illustrated) in the *Wireless World*, 10th April, pp. 389–390. In this latter summary it is mentioned that Lindenberg observations have shown that surfaces of air discontinuity between sender and receiver diminish the received energy, while over the sender they increase the received energy. It is also mentioned, regarding the Störmer-Hals echoes, that Appleton has recently observed them again just at the time which Störmer predicted for their re-appearance (see March Abstracts, p. 144).

Recherches sur les Perturbations Électromagnétiques, Sismiques et Solaires (Researches on Electromagnetic, Seismic and Solar Disturbances).—A. Nodon. (*Comptes Rendus*, 4th March, 1929, V. 188, pp. 725–726.)

Results at the Santiago observatory (Chili) confirm the close relationship between these disturbances, and also show the value of the Nodon magnetograph for obtaining warning of earthquakes.

Earth Current Registration.—S. K. Banerji. (*Nature*, 30th March, 1929, V. 123, p. 506.)

The writer has succeeded in registering earth currents with lines only 250 yards long, overcoming polarisation difficulties (which ordinarily make lines of some miles' length necessary) by making the electrodes neutral with respect to the soil.

Sur l'Électrisation de Vents chargés de Neige.—A. Vincent. (*Comptes Rendus*, 25th March, 1929, V. 188, p. 928.)

In Canada, snow lifted from the ground by the wind is so electrified (presumably by friction) that half-centimetre sparks can be drawn from a small aerial against which it is driven. *Cf.* dust winds in China, May Abstracts.

Theoretical and Field Investigations of Lightning.—C. L. Fortescue, A. L. Atherton, and J. H. Cox. *And* **Lightning: Progress in Lightning Research in the Field and in the Laboratory.**—F. W. Peek. (*Journ. Am.I.E.E.*, April, 1929, V. 48, pp. 277–280 and 303–307.)

PROPERTIES OF CIRCUITS.

Note sur le Calcul des Étages multiplicateurs de Fréquence à Triodes (Note on the Calculation of Triode Frequency-multiplying Stages).—J. Marique. (*L'Onde Élec.*, January, 1929, V. 8, pp. 1–19.)

The author writes:—"In spite of numerous articles on quartz-regulated transmitters—in which triode frequency multiplication is involved—little information exists on this subject. We have thought that, making the hypotheses generally allowed for valves functioning as amplifiers (*i.e.*, sinusoidal nature of grid and plate voltages) and using the static characteristics, it ought to be possible to calculate at least the order of magnitude of the phenomena involved in frequency multiplication; particularly the power that one could hope to draw from a valve so used. We put forward a theory which we consider enables one by quick calculations to choose the most suitable design of valve and to determine the values of inductance, capacity, polarising voltages, in fact all the elements of a multiplying stage, with an accuracy perhaps better than that obtained in the calculation of ordinary transmitters."

Tests on valve type E.303.B Radiotechnique, used as a frequency doubler, with anode voltage 1,800 and various grid voltages, gave efficiencies ranging from about 20 per cent. to 40 per cent. (with increasing grid voltage), whereas the calculated values ranged from about 13 per cent. to 40 per cent. A method of improving the efficiency is mentioned, by superposing on the fundamental E.M.F. a small E.M.F. of the required harmonic frequency: this supplementary component is always present in triode generators, and its amplitude and sign can be adjusted by inserting, in the anode circuit of the preceding stage, a circuit tuned to the harmonic and coupled to the grid circuit of the multiplying stage.

Notes on Grid-Circuit Detection.—J. R. Nelson. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 551–561.)

Author's summary:—A dynamic method of finding $\delta^2 i_g/\delta e_g^2$ or $\delta k_g/\delta e_g$, the main term in grid-circuit rectification, is given. This method is based upon formulas given by Chaffee and Browning and consists in calculating $\delta k_g/\delta e_g$ from the change of D.C. when a known A.C. input voltage is applied to the grid. The values of $\delta k_g/\delta e_g$ found by the dynamic method are compared with the values found by the usual method. The effect of frequency, internal grid resistance, and external resistance on the detection voltage introduced in the plate circuit are also considered. An experimentally determined curve is given showing the detector frequency distortion of a commercial set for a 2-megohm grid leak and for a ½-megohm grid leak.

Le Mécanisme de la Stabilisation des Oscillations dans un Oscillateur à Lampes (The Mechanism of the Stabilisation of Oscillations in a Valve Oscillator).—J. Mercier. (*L'Onde Élec.*, January and February, 1929, V. 8, pp. 29–36 and 60–67.)

An investigation of the building-up process leading to a steady state. It first assumes that the plate current-grid voltage characteristic is a straight line, and neglects the effect of grid current; later, the modifications which must be made to adapt the conclusions reached, in order to fit in with actual conditions, are considered.

Zur Frage über die Anlaufvorgänge im Röhrengenerator (The Starting-up Processes in the Valve Generator).—G. Ostroumoff. (*Zeitschr. f. Fernmeldetech.*, No. 10, 1928, V. 9, pp. 145–147.)

The building up of oscillation, at switching on, is investigated by glow lamp oscillograph. The three-electrode valve in the ordinary reaction arrangement is to be regarded as a negative resistance in shunt connection.

The Response of H.F. Circuits to Steady and Transient Modulation.—W. B. Medlam. (*Journ. Inst. Wireless Tech.*, September, 1928, V. 2, pp. 35–72.)

Author's summary:—A theoretical investigation of the behaviour of H.F. resonant circuits when supplied with a complex modulation. Formulæ are developed for the effective modulation present in the voltage across the condenser of a resonant circuit, with various valve couplings, and this is compared with the modulation present in the input to the circuit, both in amplitude and phase. Numerical results are calculated, and curves are given showing quantitatively how the results depend on the values of the circuit constants, and on the carrier frequency and character of the modulation. The conditions for the faithful reproduction of a transient modulation envelope are determined, and the results are applied to numerical cases.

Le Transformateur à Basse Fréquence "Philips" (The "Philips" L.F. Transformer).—A. van Sluiters. (*Rev. Gén. de l'Élec.*, 30th March, 1929, V. 25, pp. 485–491.)

The paper begins with the theory of the L.F. intervalve transformer and the determination of the values of the amplification per stage for low, medium and high frequencies. The theoretical results are applied to the actual case of the Philips transformer.

Untersuchungen an Drosseln mit geschlossenem Hypernik-Kern (Investigations on Chokes with Closed Hypernik Cores).—P. Hermanspann. (*Zeitschr. f. Hochf. Tech.*, March, 1929, V. 33, pp. 81–84.)

A study of the behaviour of such choke coils in resonant circuits fed with sinusoidal A.C. of various frequencies (50–1,000 cycles per sec.). The advantages of this iron-nickel alloy over ordinary dynamo show up properly only for very weak fields, the *B/H* curve here rising very sharply. A special property is that the inductance of such a coil can be increased by a small super-imposed D.C. magnetising current. This effect decreases as the frequency is lowered, but can be shown to exist even at 50 cycles.

Vector Presentation of Broad-Band Wave Filters.—R. F. Mallina and O. Knackmuss. (*Journ. Am. I.E.E.*, April, 1929, V. 48, pp. 265–269.)

The function of such a filter, of the iterative adder type, is expressed in terms of two characteristic vectors. The diagram of these shows clearly that the angle between them is the phase shift of the filter, that the natural logarithm of the ratio of their magnitudes is the attenuation, and the relationship between a mid-series and a mid-shunt structure. The equations for such filters can be derived in a very simple manner from the geometry of one vector triangle.

Les Caractéristiques des Circuits contenant une Bobine d'Inductance à Noyau de Fer et des Condensateurs (Characteristics of Circuits containing Iron-cored Inductances and Condensers).—P. Kalantarcff. (*Rev. Gén. de l'Élec.*, 2nd March, 1929, V. 25, pp. 315–322.)

An application of graphic methods to the predetermination of the current/voltage and current/frequency characteristics in various complex circuits.

A Complex Pendulum driven by Two Pendulums having Commensurate Periods.—H. M. Browning. (*Phil. Mag.*, April, 1929, V. 7, No. 44, pp. 721–729.)

TRANSMISSION.

Ultra-short Waves (15–20 cms.).—G. Beauvais. (*Rev. Gén. de l'Élec.*, 16th March, 1929, V. 25, pp. 393–394.)

A paper read before the Soc. franç. des Élec., containing much the same matter as the same writer's *Comptes Rendus* paper (March Abstracts, p. 149). He puts 1.5 m. as the lowest limit for ordinary methods of production, owing to the electron time of passage being comparable with the oscillating period (*cf.* Hollmann, April Abstracts, p. 208). By the use of his super-regenerative receiver he obtained ranges of the order of 600 metres with 15–20 cms. waves. By using parabolic mirrors at each end, he obtained "satisfactory reception" with "only one L.F. valve" at a distance of 10 km.; the tolerance of the angle of the mirror at the receiving end was 4 deg. on either side of the mean position. He considers that by improving the concentration of the beam, ranges of 30 to 40 km. should be obtained.

Die Erzeugung kürzester elektrischer Wellen mit Elektronenröhren (The Production of the Shortest Electric Waves by Valves).—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, March, 1929, V. 33, pp. 101–107.)

Final part of the long survey referred to in April and May Abstracts. It deals first with the theoretical explanations of the electron oscillations: the multitudinous results described in the previous parts show that the simple B-K theory requires a good deal of expansion. Up to the present no complete theory has been found to cover all the known facts, but various workers have brought forward partial theories which the writer summarises, one after the other. A later section deals with the energy of electron-oscillations. The writer has obtained up to 0.5 ampere for a 66 cm. wave and 0.12 A. for a 38 cm. wave, a single valve being used in each case. Scheibe has used valves in parallel, and finds that the energy from two valves is more than twice (it may be as much as seven times) the energy from one.

Electron oscillations in a magnetic field are then dealt with—Žaček and Yagi and Okabe (split magnetron). The final section is concerned with the filtering-out of harmonics, and the paper ends by announcing the production of the shortest wave yet attained—3.5 cm., by Potapenko, using a modified Barkhausen "brake-field circuit" and grid voltages 100–150. The complete paper includes a bibliography of 72 items, of which a third are in this final part.

Die Erzeugung von kurzwelligen ungedämpften Schwingungen bei Anwendung des Magnetfeldes (The Production of Short Wave Undamped Oscillations by the Use of a Magnetic Field).—A. A. Slutzkin and D. S. Steinberg. (*Ann. der Physik*, 12th March, 1929, Series 5, V. 1, No. 5, pp. 658–670.)

"Intensive" oscillations corresponding to wavelengths down to 7 cm. are produced by a special diode (similar results, but much weaker, were obtained with commercial triodes). Relations between wavelength, electron path times, magnet field, etc., etc., were investigated. For the shortest (7 cm.) wave the anode voltage was 780 v., the field 1,617 Gauss, the emission current 4.7 mA. It was possible to calculate the wavelengths with very good accuracy from the electron path time.

STUDY AND MEASUREMENT OF ULTRA SHORT WAVES.—B. Mazumdar. (*Indian Journ. Phys.*, 30th September, 1928, V. 3, pp. 77–93.)

Wavelengths round 5 m. were obtained with one, or two, three-electrode valves, in circuits such as van der Pol and Englund used, where reaction was due to the grid-plate capacity. A theory has been worked out for the modified van der Pol method, giving good agreement between calculated and observed wavelengths.

ÜBER UNGEDÄMPFTE ELEKTRISCHE ULTRAKURZWELLEN MIT DEMONSTRATIONEN (On Ultra-short Undamped Electric Waves, with Demonstrations).—K. Kohl. (*Zeitschr. f. tech. Phys.*, March, 1929, p. 107.)

Short description of a lecture. 14 cm. waves were generated in a small valve "whose most important element was a small spiral" set into undamped oscillation by electron movements. Reflection, polarisation, diffraction, etc., were demonstrated. The use of reflectors at transmitter and receiver showed the possibility of covering "large distances with small expenditure of energy." Distilled water was shown to be almost opaque to these waves, paraffin oil to be very transparent.

VALVES FOR GENERATING ULTRA-SHORT (30 cm.) WAVES.—W. Wagner. (See under "Stations Design and Operation.")

A PIEZO-CONTROLLED VALVE GENERATOR. (Amer. Patent 1,683,130, Gebhard, pub. 4th Sept., 1928.)

In order to obtain the greatest amount of power with as few stages as possible, a condenser is connected between grid and anode.

By adjusting this condenser, the oscillation process can be so regulated as to give maximum output.

A SHORT-WAVE PIEZO-CONTROLLED TRANSMITTER. (German Patent 468629, Lorenz, pub. 19th November, 1928.)

Anode and grid circuits are both aperiodic, and are coupled together for reaction. A special crystal is provided for each wavelength, each crystal being furnished with a non-interchangeable mounting so that its introduction automatically changes the switching to suit itself.

DIRECTIONAL ANTENNÆ. (French Patent 643559, S. F. R., pub. 19th Sept., 1923.)

A continuous aerial conductor is zig-zagged along a cylindrical surface. When the axis of the cylinder is vertical, radiation is vertically polarised and radiates horizontally.

FADING ELIMINATION. (German Patent 467595, Telefunken, pub. 2nd November, 1928.)

The transmission of the same signal on more than one wavelength simultaneously is a known method of fading elimination. The invention refers to the choice of two wavelengths differing in frequency by a number which is double the frequency of a convenient audible note: so that by the same heterodyne, the two waves will produce this same note.

PREVENTION OF DISTURBING EFFECTS IN H.F. GENERATORS. (French Patent 643013, Lorenz, pub. 8th September, 1928.)

The use of mercury for balancing, to avoid the production of "trill" (*cf.* Hahnemann, February Abstracts, p. 102.)

FREQUENCY MULTIPLICATION BY IRON-CORED CHOKES. (German Patent 468672, Dornig, pub. 19th November, 1928.)

AN EXAMINATION OF A.C. PLATE SUPPLY: CONSIDERATIONS GOVERNING THE USE OF SELF-RECTIFICATION.—R. A. Hull. (*QST*, February, 1929, pp. 23–27 and 88.)

The simplicity of self-rectification can be made use of without loss of constancy of frequency if the set is designed and adjusted according to the lines here given. But the author hopes that the new mercury vapour rectifiers (see Pike and Maser, under "Subsidiary Apparatus") will be a still better and simpler solution.

RECEPTION.

RECENT DEVELOPMENTS IN SUPERHETERODYNE RECEIVERS.—G. L. Beers and W. L. Carlson. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 501–515.)

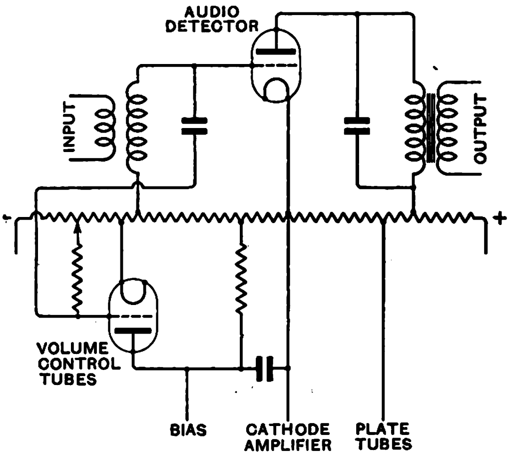
Authors' summary:—"Major electrical elements of a modern superheterodyne receiver—tuned radio-frequency amplifier, intermediate frequency amplifier detector and audio-frequency amplifier—are briefly discussed in light of recent developments. A practical automatic volume control is described. Curves illustrating the major performance characteristics of the receiver are shown."

Among various points in the paper the following may be quoted:—In past superheterodyne receivers the intermediate frequency has usually been in the neighbourhood of 40 or 50 kc. This choice resulted from the ease of obtaining a stable amplifier for a frequency in this region, having the necessary amplification and the desired selectivity. Now, however, it is realised that (as shown by a curve of selectivity of two tuned circuits) the higher the intermediate frequency, the less the possibility of encountering interference from stations separated by twice the intermediate frequency. From the curve it is seen that this interference for a 40 kc. amplifier would be 350 times that for a 400 kc., and 60 times that for a 200 kc., amplifier. 180 kc. is suggested as the best compromise between amplification, stability, selectivity, and undesired responses.

Discussing the radio-frequency circuits, a transformer is described giving improved fidelity, its primary having a large number of turns making it resonant to a frequency below the low-frequency end of the range. With a primary thus tuned to a lower frequency than the secondary, the plate circuit has a capacitive reactance and the voltage fed back through the valve capacity is therefore of such a phase as to oppose the applied grid voltage, and will reduce this to a fraction of its normal value. Methods are shown for overcoming this difficulty.

In the audio-frequency system, distortion,

hum, etc., are reduced by using a plate circuit detector and only one audio-frequency stage. Regarding automatic volume control, the writers say that the chief objections to past systems have been the number of adjustments required and the use of separate voltage supplies for certain



parts of the circuit. The arrangement shown in the schematic diagram overcomes these objections.

Aerial Coupling for Short-Wave Reception.—T. S. Rangachari. (*Electrotechnics*, Bangalore, March, 1929, pp. 175–177.)

An investigation of coupling in the reception of wavelengths of the order of 30 m. by a detector with reaction (followed by L.F. amplification) with a view to determining the conditions for maximum energy transfer. It is shown that the coupling required may be extremely small even when the aerial is far from resonance: which explains the experience that even though the aerial is apparently not coupled to the receiver but allowed to remain close by, quite satisfactory reception is sometimes obtained. Another point considered is the ratio between the energy transferred for optimum conditions for an untuned aerial and that which would be transferred if the aerial were also tuned: this ratio depends upon the nearness of the natural wavelength of the aerial to the received wavelength. Moreover, if the aerial wavelength exceeds about twice the received wavelength a variation in the size of the aerial does not appreciably affect signal strength.

La Qualité de la Réception Radiophonique (Quality of Radiotelephonic Reception).—P. David. (*L'Onde Élec.*, February, 1929, V. 8, pp. 41–59.)

First instalment. The causes of distortion are divided into three classes: incorrect reproduction of frequencies: incorrect reproduction of amplitudes: superposition of parasitic vibrations. These types of distortion are examined for their origins: they are not looked for in the transmitter, partly because this has been dealt with by Deloraine (*ibid.*, January-February, 1928), but chiefly because the writer considers that the modern transmitter gives practically perfect results: they are sought in the actual transmission through space, in the receiving aerial, in selectivity against atmospherics and interference, in H.F. amplification, reaction, and detection. Here the first instalment ends. A few dicta may be quoted:—Reaction, voluntary or otherwise, should be very weak for short waves, inappreciable for long waves and utterly banned from the "intermediate frequency amplifier" of superheterodyne reception: in the latter, deliberate damping in the coupling circuits may be advisable. With regard to frequency fidelity, "between 80 and 5,000 p.p.s. the ratio of the amplitudes of the least favoured and the most favoured frequencies should be between ½ and 1." Regarding the cutting out of interference, Borias' proposal (March Abstracts, p. 152) to detune the circuits from the carrier wave in such a way as to receive unsymmetrically the two side-bands, and to compensate for the weakening of the one by the strengthening of the other, is favourably mentioned: but fear is expressed that the adjustment—to obtain the desired result—would be beyond the average operator.

La Qualité des Réceptions radiophoniques (Quality in Radiotelephonic Reception).—B. Decaux. (*T.S.F. Moderne*, October, 1928, V. 9, pp. 604–616.)

In dealing with the three main classes of distortion-producing factors (those in the R.F., rectifying, and L.F. circuits) the writer maintains that the first, which are often ignored, are often the most important: reaction, sharpening the resonance curves, is allowed to suppress the higher frequencies. Proper use of band-pass filters is not yet being made in amateur reception. Among the steps to be taken to avoid L.F. distortion, the choice of a loud speaker by trial with the set itself is mentioned.

Récepteur pour Sous-Marins (Receiver for Submarines).—(*Bull. de la S.F.R.*, January, 1929, pp. 15–19.)

A special 8-valve receiver for a wave-range of 250–6,000 m., the long waves being indispensable for communication when the submarine is submerged.

How Much Selectivity?—J. E. Smith. (*Rad. Engineering*, February, 1929, V. 8, pp. 44–45.)

An article dealing with the relation between selectivity and circuit resistance, and the rôle regeneration plays in modern receivers. Quality is also considered: "the amount of side-band cutting that occurs in even rather broad receivers is surprising. And when we obtain such a great amount of selectivity as is required [for modern conditions of congestion], can you imagine how much more of the side-bands is lost to us? . . . And in spite of it all, designers still go on trying to bring out stronger and stronger the low notes. Is it any wonder that so much of the music coming from loud speakers is drummy?" The suggestion is approved that it would be well to make one part of the receiver compensate for the losses in another

part: for instance, in order to compensate for the side-band cutting, in the R.F. amplifier, of the higher frequencies, the L.F. amplifier might be designed to amplify these frequencies more strongly.

MORE AMPLIFICATION FROM SCREEN-GRID VALVES: DOUBLING THE STAGE GAIN AND MAINTAINING STABILITY.—A. L. M. Sowerby. (*Wireless World*, 24th April and 1st May, 1929, V. 24, pp. 424–426 and 456–458.)

In spite of the hopes aroused by the screen-grid valve, the greatest amplification by the ordinary method of using it is not much more than 40 per stage—which is not as much as can be obtained with a good 3-electrode stage. This comparative failure is due to the fact that the inter-electrode capacity has only been partially removed by the screen-grid. By the system of neutralising described, the writer obtains amplifications from 100 upwards.

IMPROVING SHORT-WAVE PHONE RECEPTION.—R. A. Hull. (*QST*, March, 1929, V. 13, pp. 9–20.)

"A modern super-heterodyne for short-wave phone, code, and general broadcasting."

AERIALS AND AERIAL SYSTEMS.

THE RADIATION RESISTANCE OF BEAM ANTENNÆ.—A. A. Pistolkors. (*Proc. Inst. Rad. Eng.*, March, 1927, V. 17, pp. 562–579.)

By the Poynting vector method of calculating the power radiated from an aerial it is impossible to obtain the contributions, to the radiated power, of different parts of the aerial system, as is sometimes desirable to do when dealing with practical cases. This disadvantage is not present in the "induced E.M.F. method" proposed by Brillouin in 1922, based on the electromagnetic field equations in the form employing the retarded potentials of Lorentz. This method was applied by Kliatzkin in the analysis of the radiation from a vertical earthed wire, and the present paper applies it to several types of beam aerials. New formulæ are deduced and some interesting results obtained showing the distribution of the radiated power among the different wires of beam aerials, and giving the numerical values of the radiation resistance in various cases (synphase, antiphase, and Marconi three-stage aerials). The radiation resistance in the presence of a perfect conducting plane is also considered. A table of values of the components of radiation resistance is added for practical use.

STRAHLUNG VON ANTENNEN UNTER DEM EINFLUSS DER ERDBODENEIGENSCHAFTEN. (A) ELECTRISCHE ANTENNEN; (B) MAGNETISCHE ANTENNEN (Radiation from Antennæ under the Influence of the Properties of the Ground. (A) Electric Antennæ; (B) Magnetic Antennæ).—M. J. O. Strutt. (*Ann. der Physik*, 6th April, 1929, Series 5, V. 1, No. 6, pp. 721–772.)

The first question, "What effect has the earth's finite conductivity on the radiation of horizontal and vertical aerials at finite radiation-angles with the earth?" is answered by direct integration of the differential equation, leading to formulæ for the radiation of horizontal and vertical dipoles and for aerials at any angle. For vertical dipoles these are identical with Weyl's and T. L. Eckersley's results. The second question, "What fraction of the total radiation is lost in the earth?" is answered in certain special cases from which other cases may be inferred approximately. The third question, "How does the useful radiation (and the useful radiation-resistance) alter with increasing height of aerial above the earth?" and the fourth, "Is a horizontal or a vertical aerial, at a given height above the earth, the more favourable as regards useful radiation?" are dealt with together, the results contradicting Sommerfeld's opinion that the horizontal aerial is always worse than the vertical: either may be better than the other, according to the height and the condition of the ground.

The paper is illustrated by tables and curves.

TRANSMITTING AERIALS FOR BROADCASTING STATIONS.—P. P. Eckersley, T. L. Eckersley and H. L. Kirke. (*Journ. I.E.E.*, April, 1929, V. 67, pp. 507–526.)

The complete paper, with discussion, a summary of which was dealt with in April Abstracts, p. 211.

THE RESONANCE EFFECT OF RECEIVING ANTENNÆ.—C. Coston. (*QST*, April, 1929, V. 13, pp. 51, 55.)

Methods of mitigating this effect (which prevents the oscillation of a regenerative receiver on certain frequencies, and the most efficient operation at all frequencies) without the use of a "coupling valve" (an untuned R.F. stage).

ISOLATEURS SUSPENDUS: ÉTUDE DE L'INFLUENCE DE LA LONGEUR DES ATTACHES (Suspended Insulators: the Influence of the Length of the Connecting Links).—G. Viel. (*Rev. Gén. de l'Élec.*, 22nd December, 1928, V. 24, pp. 945–948.)

The distance between individual insulators in a chain is of importance owing to their effect on one another, resulting in a decrease of effective insulation. This result is quantitatively examined in this paper.

EXPERIMENTS WITH MULTI-FEED AERIALS.—W. H. B. de M. Leathes. (*Journ. Inst. Wireless Tech.*, September, 1928, V. 2, pp. 5–18.)

Effect of feeders on (*a*) natural wavelength, (*b*) resistance, (*c*) radiation. General remarks on the comparison between Inverted *L* and Radial aerials as to radiation: Spurious oscillations in a multi-fed aerial: Losses. In the discussion, G. L. Morrow questions whether the use of an earth screen does not make the whole system radically different from the case where the aerial is earthed. Stations working on wavelengths round 30 m. are incapable of being D.F.'d at short or medium ranges, especially in marine work: but a multi-feed system with a screen whose electrical and physical

constants are as near as possible to those of the aerial can be D.F.'d on these wavelengths at quite small ranges—suggesting that such a combination approximates to a loop. He corroborates the author's statement that directive radiation decreases the radiation resistance.

VALVES AND THERMIONICS.

THE OPERATION OF RADIO RECEIVING TUBE FILAMENTS ON ALTERNATING CURRENT. Part II.—K. H. Kingdon and H. M. Mott-Smith, Jr. (*Gen. Elec. Review*, April, 1929, V. 32, pp. 228–232.)

Sequel to a previous article (*ibid.*, March, 1929, pp. 139–148) dealing with the reduction of disturbances when using A.C. heated valves as amplifiers, this part discusses the subject of such valves used as grid-leak detectors.

Authors' summary :—" When the grid is made positive enough to take electron current, disturbances occur in the grid current which are similar to those in the anode current, which were described in Part I [primary potential, magnetic, and temperature ripples]. If the grid current flows through a grid-leak resistance, the fluctuations in grid current cause fluctuations in grid potential, which in turn give rise to ' secondary ' ripples in the anode current. Usually the secondary potential ripple is of by far the greatest importance. This is a double-frequency ripple, ordinarily of opposite phase to the primary potential ripple. It is discussed quantitatively in Section VII. This ripple is so large as to give rise to serious disturbances in a tube used as a grid-leak detector, if the filament drop is greater than about 0.1 volt." A summary of Part I is also given. It includes mention of the method of opposing voltage ripple to magnetic ripple so as to neutralise these two components by a suitable choice of voltage and filament resistance.

CONTROL OF AN ARC DISCHARGE BY MEANS OF A GRID.—A. W. Hull and I. Langmuir. (*Proc. Nat. Acad. Sci.*, March, 1929, V. 15, pp. 218–225.)

By an exposition of the condition of affairs in a mercury vapour three-electrode valve, the writers show that grid control of the arc current (once this has started) can only be obtained by using closely spaced grid wires and not too great currents, so that the positive-ion sheaths of adjacent wires touch or overlap. They mention that this kind of control, though restricted, has many interesting features which they propose to report on later.

The present paper deals with grid control in such a valve *before* the arc has started. No ions are present to form the sheaths, and the electrostatic fields are the same as in a vacuum valve ; if the valve has $\mu = 10$, then 10 volts negative grid potential will prevent any current from flowing for an anode voltage of 100. But if this bias is decreased a little, the small electron current now allowed to flow produces ions which promptly form sheaths round the grid wires, and the current instantly rises to a value limited only by the filament emission or the circuit resistance.

(By this extremely sensitive relay action, the voltage of transients of only a fraction of a volt and less than a microsecond in duration can be measured.)

The control just described is a particularly effective way of turning the current *on* (thousands of amperes may be turned on by a fraction of a volt applied to the grid) but it cannot turn it *off.* The current however can turn itself off if alternating anode voltage is used : it will cease at the end of the positive half-cycle. At the next positive half-cycle, it will start or not start according to the grid voltage : thus grid control of the average current is obtained. Another and better method of control is obtained by using alternating grid voltage and controlling its phase with respect to the anode alternating voltage : as for example by determining the phase by the rate of charging of the grid condenser by photoelectric current—in which case the average current through the valve varies continuously and uniformly as the illumination is varied.

In the case of direct current anode supply it is necessary to produce a momentary drop of anode voltage to such a value that ionisation stops, and to maintain this drop long enough for the ions to diffuse to the electrodes.* This can be done in various ways, the most useful perhaps being by means of a second valve. Such a pair of valves gives an arrangement in which the current can be shifted at will from one valve to the other: it can be used to convert direct into alternating current.

HOT-CATHODE THYRATRONS.—A. W. Hull. (*Gen. Elec. Review*, April, 1929, V. 32, pp. 213–223.)

Part I of a paper on the practical aspects of the gas- or vapour-filled triode rectifier referred to above.

CALCULATIONS ON VACUUM TUBES AND THE DESIGN OF TRIODES.—Y. Kusunose. (*Res. Electrot. Lab. Tokyo*, September, 1928, No. 237, 163 pp.)

Dealing first with diodes, the writer shows how the Langmuir equation is applied to the design of these ; minor effects (initial velocity of electrons, superposition of anode current on filament current, etc.) are neglected for practical purposes. He shows how, for example, the quantity A (effective anode area) is best reckoned, confirming by examples in which the calculated and observed curves agree very well. He mentions that when the filament is supported by a complex structure (as in many high-power rectifiers) the latter must be considered as the grid of a triode and the characteristic computed by the triode equation assuming zero grid voltage. Numerous examples, on various types of valve, are given.

Passing on to triodes, he makes use of Eccles' statement that the current through a (cylindrical) triode is the same as that through a diode of the same length and of radius equal to that of the surface on which the grid is wound, provided that the voltage applied to the diode is $\frac{e_a + \mu e_g}{1 + \mu}$ where

*Time for de-ionisation is considered in the paper, and a semi-empirical formula given.

μ is the amplification constant. Here, again, the writer shows how, according to his experimental results, the effective grid area should be measured. Numerous static characteristics, calculated and observed, are shown; agreement being excellent. For roughly calculating grid current (for low positive grid voltages, where it is small compared with anode current) he uses formulæ given in Lange's paper (Abstracts, 1928, V. 5, p. 520, etc.). He shows how to calculate the amplification constant, mutual conductance, anode impedance, and saturation current.

The next part of the paper deals with the determination of the behaviour of a triode, from its static characteristics, in any given circuit arrangement. For this purpose the writer obtains curves giving the values of the D.C. and A.C. components of the anode current under any conditions; from these he derives the "dynamic characteristic diagram," the use of which allows the behaviour of the triode to be calculated. Among numerous examples worked out, the following is one chosen as an illustration: a triode, type VM-100, has a rating as shown in a table: its optimum operating conditions used as a power amplifier for distortionless reproduction are required. The last chapter deals with the design of triodes for particular requirements.

Electronic Emission in a Vacuum Tube.—L. Tieri and V. Ricca. (Summary in *Science Abstracts*, Sec. A., 25th March, 1929, p. 257.)

An experimental investigation of the relation between the variations of filament current and the variations of electronic current, when the plate/filament voltage is varied. The effect on the filament current is connected with the work of separation of the electrons, and can therefore be used for determining the intrinsic potentials of some metals.

Phases of the Thermionic Saturation Current: Thermionic Valve Circuit with Condenser in a Derived Circuit.—C. Dei. (Summaries in *Science Abstracts*, Sec. A., 25th March, 1929, p. 257.)

Two papers from the Acad. Lincei, Rome. They both deal with a mathematical investigation of the phases and intensity of current in circuits which include a diode valve at saturation. The current intensity does not reach a value rigorously constant, because with increase of anode/filament voltage it increases approximately linearly.

Émission thermo-ionique de Tubes de Cuivre remplis de Sels (Thermionic Emission from Copper Tubes filled with Salts).—T. Pecsalski and J. Chichocki. (*Comptes Rendus*, 4th March, 1929, V. 188, pp. 699–701.)

A tube of copper was filled with a salt and then drawn out till its diameter was almost quartered, so that the salt completely filled the tube. The tube was arranged along the axis of a much larger tube, these two tubes being in a container exhausted to 10^{-6} mm. A current was passed through the salt-filled tube, and a P.D. (80 v.) applied across the two tubes. A thermionic current, rising to 2×10^{-7}A. in about 40 minutes, was obtained for positive emission, a smaller value, appearing more slowly, for negative; this was with $NiCl_2$ in the tube. With an empty tube no thermionic current could be obtained. Further details are given.

Un Abaque de Classification pour les Triodes de Réception (An Abac of Receiving Valve Classification).—B. Decaux. (*L'Onde Élec.*, January. 1929, V. 8, pp. 37–40.)

The principal types of receiving valves sold in France are included in this chart, which shows their amplification coefficients, internal resistances and spheres of usefulness.

The UV-861.—H. P. Westman. (*QST*, February, 1929, pp. 41–43 and 88.)

Full description and details of a 500-watt screen-grid transmitting valve, normal anode voltage 3,000, suitable for short wavelengths. Its use is described in a following article (pp. 44–48) by C. C. Rodimon.

Mica Screen for Locating the Deposition of Magnesium in Valves.—(*French Patent*, 646,813, Loewe, pub. 16th November 1928.)

A specially arranged mica screen prevents the magnesium from depositing itself near the stem of the bulb or on the electrodes. It is found that a better vacuum is thus maintained, chiefly because any magnesium deposited on the anode is liable to give up its gas when the valve is in use owing to the heat produced.

Burn-out of Incandescent Lamps.—(*Gen. Elec. Review*, April, 1929, V. 32, pp. 206–212.)

Gas-filled lamps burn out at a much smaller loss in weight than vacuum lamps. Various factors are found to contribute to this result: change in crystalline structure is the "most spectacular"; leakage currents and the chemical effects of the gas are also important.

DIRECTIONAL WIRELESS.

Prevention of Locating by Direction-finding.—(*German Patent* 467,693, Telefunken, pub. 9th November, 1928.)

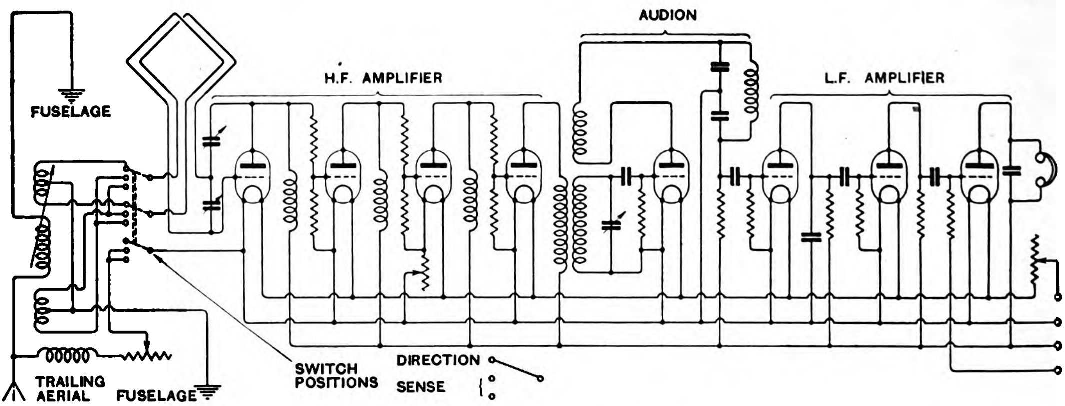
The direction of a transmitting station is concealed by making its directively radiating aerial rotate, or by using a number of directive aerials and connecting them in succession to the transmitter. Directive aerials usually send out a small component which is not directed: this must be compensated for by an auxiliary aerial.

Le Chemin du Rayon Électromagnétique (The Path of the Electromagnetic Ray).—de la Forge. (*QST Franç.*, December, 1928, pp. 6–11.)

Conclusion of the long analysis of the Radio Research Board report on Direction Finding (Abstracts, 1928, V. 5, p. 642).

DER BORDPEILEMPFANGER IM FLUGZEUG (The Direction-finding Receiver for Use on Board Aircraft).—M. H. Gloeckner. (*Zeitschr. f. Hochf. Tech.*, March, 1929, V. 33, pp. 92–101.)

A paper on the new Telefunken D.F. outfit and the series of tests leading up to its design. The writer admits that both the two main systems of D.F. have their advantages, but points out that for long distance work the D.F. on the aircraft itself is always preferable because of the greater power of the ground station. After enumerating the various requirements which this new outfit had to fulfil, he goes on to describe the methods adopted for neutralising the antenna effect of the frame (by means of an auxiliary aerial, generally trailing, though a photograph of a Junkers F.13 shows a fixed auxiliary aerial) and for determining sense. The diagram reproduced shows these arrangements.



The rest of the paper deals with the installation of the apparatus and its correction for effects due to metal parts, etc. Fischer's work (see Abstracts, 1928, V. 5, p. 522) is made use of. Calibration is carried out on the ground, the aeroplane being rotated on a turn-table while receiving from a fixed station 20 km. away.

REPÉRAGE DES DIRECTIONS FIXES AU MOYEN D'ONDES HERTZIENNES—RADIO - ALIGNEMENTS (Course-Setting by Hertz Waves—Radio Alignments).— — Aicardi. (*L'Onde Élec.* January, 1929, V. 8, pp. 20–28).

In trials of this method, using a D.C. input of 200 w. at the transmitting ground station, an aeroplane has been guided with an accuracy of the order of 1 degree up to a distance of about 60 km. 60 m. waves were employed, transmitted simultaneously from two vertical aerials spaced about 45 m. apart (consisting of copper tubes 6–8 metres high, with radial counterpoise). One aerial sends out continuous waves, the other modulated waves of the same length but of much smaller amplitude. Along the nodal lines (of which there may be one, two or more, depending on the ratio of aerial spacing to wavelength*), these two sets of waves give a resultant field of high and *constant* strength.

In order to make it easier for the aeroplane to keep to its course, and to find it again when it has been lost, the nodal lines are periodically swept through an angle of 5 to 10 degrees by the use of a rotating condenser in parallel with the aerial capacity. The combined results are as follows: signal strength, which has been practically constant outside the swept zone, suffers a periodic and increasing weakening as this zone is approached. As the zone is penetrated, the minima become of zero strength and double in number, becoming equally spaced when the axis of the zone (the true course) is reached. It is said that this equidistant spacing is very easily observed.

A further refinement allows the observer to see on which side of the course he is at any moment: this consists in changing the modulation frequency, for a very short period, once in every complete "sweep." On one side of the axis this frequency-change follows the minimum (or group of two minima if the zone is already penetrated) ; on the other side, it precedes it.

RADIO DIRECTION-FINDING BY TRANSMISSION AND RECEPTION (With Particular Reference to its Application to Marine Navigation).—R. L. Smith-Rose. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 425–478.)

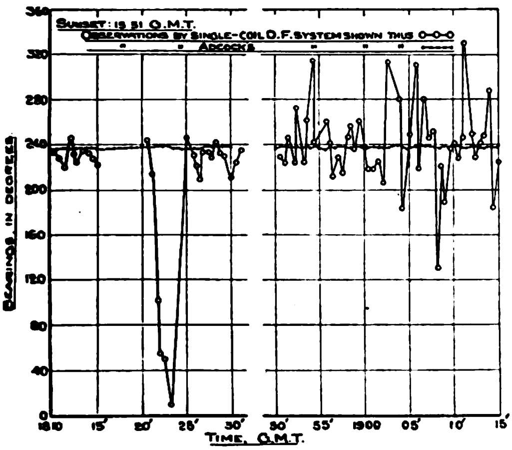
An abridgment of this paper was read at the 1928 U.R.S.I. meeting in Brussels. Author's summary :—" This paper presents a critical *résumé* of the performance of apparatus employed for radio direction determination either by transmission or by reception. After an historical summary of results obtained in various parts of the world, a brief description is given of the fundamental principles underlying radio direction-finding. In this section attention is drawn to the application of the principle of reversibility to this art, by the aid of which the behaviour of directive radio transmitters can be largely

* If the spacing is slightly less than half the wavelength, only one nodal line is obtained: "sufficient" accuracy was found in this case, but the accuracy is greater with larger values of the ratio.

predicted from the more numerous results and greater experience already obtained with directional receivers.

"The next two sections of the paper give a review of the results obtained in Great Britain during the course of extensive investigations into this subject during the past seven years. Observations obtained from thirteen direction-finding receiving stations, specially erected for the purpose, have been carefully analysed and the performance of the apparatus studied under a variety of conditions, including operation in daylight and darkness, and both oversea and overland. In addition, some two years have been spent in studying the performance of a rotating-loop beacon transmitter, by means of which accurate radio bearing can be obtained with any type of receiving apparatus.

"The later portions of the paper deal with the application of direction-finding to marine navigation, and with the possible effect of coastal and night errors in connection therewith. The production of night errors on closed loop receivers by the horizontal component of the electric force in downcoming waves is explained, and a demonstration is given of the manner in which the Adcock aerial system gives freedom from such errors. The paper concludes with a discussion of the relative advantages of direction-finding by transmission and reception for navigation purposes. A bibliography of the subject is appended."



Observations of Bearings on Bournemouth, Dec. 10, 1925 ($\lambda = 386$ *m.*).

The figure reproduced shows the type of result obtained with the Adcock direction-finder (in which the errors due to down-coming waves polarised with the electric force horizontal are avoided) as compared with simultaneous observations on the ordinary closed-coil direction-finder.

ACOUSTICS AND AUDIO-FREQUENCIES.

APPARENT EQUALITY OF LOUD-SPEAKER OUTPUT AT VARIOUS FREQUENCIES.—L. G. Hector and H. N. Kozanowski. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 521–535.)

Authors' summary:—A type of alternation phonometer has been developed which permits rapid switching of power at two frequencies to the same loud speaker without the distracting effect of the transients that would result from ordinary types of commutation. This result is obtained by the use of rotating condensers to provide variable capacitative reactance in the input circuit of the power amplifier that operates the speaker. The power consumed by the loud speaker is measured with a specially constructed wattmeter of the electrodynamometer type and the output of the loud speaker is measured by means of the torques produced on a Rayleigh disc. With the aid of the alternation phonometer and an additional capacitative reactance, the observer is able to adjust the power input to the loud speaker until two tones of different frequencies appear to have the same intensity. The purpose of the research was to develop a method for the comparison of loud-speaker efficiency at various frequencies that could be used in ordinary laboratories with limited equipment.

MINIMUM VALUE OF AMPLITUDE OF SECOND HARMONIC WHICH MUST BE SUPERPOSED ON FIRST HARMONIC SO THAT IT BECOMES NOTICEABLE IN AN "ORDINARY" LOUD SPEAKER.—(*Nature*, 23rd March, 1929, V. 123, p. 466.)

A paragraph on recent B.B.C. tests. With a fundamental of 900, the amplitude of the second harmonic has to be at least 3 per cent. of that of the fundamental: at higher frequencies a much greater percentage is necessary (*e.g.*, 49 per cent. for a 5,000 fundamental). "The introduction of cone loud speakers and the annulment of resonance effects by frequency filters were notable steps in advance. The efficiency of transformation of all ordinary loud speakers is very low. Some of the loud speakers, however, used in the commercial operation of 'Movietone' and 'Vitaphone' talking-film systems have efficiencies of 30 per cent. A new Western Electric loud speaker is claimed to have a 50 per cent. efficiency."

INSENSITIVE LOUD SPEAKERS AND FALSE ECONOMY.—A.L.M.S. (*Wireless World*, 20th March, 1929, V. 24, p. 301.)

Poor loud speakers often require heavy anode current, and what is saved in the price of the loud speaker may be lost many times over.

TRANSIENTS *alias* "ATTACK": NATURAL OSCILLATIONS OF LOUD-SPEAKER DIAPHRAGMS.—N. W. McLachlan. (*Wireless World*, 3rd and 10th April, 1929, V. 24, pp. 346–348 and 385–388.)

The first part describes the nature of a "transient" (a sudden change in current) and shows how it may be expected to produce the same kind of effect as is obtained by tapping the apex of a loud-speaker cone; i.e., an effect involving the natural oscillations of the diaphragm. It then outlines a series of experiments on the behaviour of various types of loud speaker under the influence of such sudden changes which occur to a greater

or less extent in the reproduction of all speech, music, etc. The second part gives the result of these experiments, in the form of oscillograms with analytical comments on each.

Vorübertrager verzerrungsfreier Verstärker (Input Transformers of Distortionless Amplifiers).—R. Feldtkeller and H. Bartels. (*E.N.T.*, February, 1929, V. 6, pp. 87–90.)

Authors' summary :—The desired width of the frequency band to be transmitted, and the data of the amplifier valves employed, definitely determine a maximum allowable transformation ratio and leakage coefficient. A simple relation is established between the top frequency and the highest amplification attainable without distortion by one valve; this amplification is independent of the width of the frequency band.

Choosing a Power Valve for the Reed-driven Loud Speaker: An Analysis of Impedance Relationship.—N. W. McLachlan. (*Wireless World*, 20th March, 1929, V. 24, pp. 298–301.)

Frequency Gramophone Records.—(*Electrician*, 5th April, 1929, V. 102, p. 428.)

A paragraph on the set of 15 double-sided records recently brought out by the Gramophone Company, giving a series of pure tones ranging over about 8½ octaves up to 8,460 p.p.s. "Provided the turntable runs exactly 78 r.p.m., the frequencies are correct to within 1 per cent." The exact amount of energy has been calibrated and is given on the labels in the form of T.U.'s above or below the energy of the 993 cycle note.

Neue Hilfsmittel für akustische Messungen (New Aids to Acoustic Measurement).—(*E.N.T.*, March, 1929, V. 6, p. 112.)

A paragraph on a new series of gramophone records providing standard frequencies. One side of the first record begins with 6,000 cycles and changes continuously down to 100. The amplitude of the needle movement is inversely proportional to the frequency. The reverse side has the same range but each note varies some ten times per second by ± 50 cycles, producing a "sliding howl." Other records give steady howls, each side covering only two frequencies.

Energiebilanz im Rundfunk (The Balance of Energy in Broadcasting).—E. Wolf. (*Elektrot. u. Masch:bau.*, 10th March, 1929, pp. 197–200.)

A paper on fidelity of transmission and reception.

The Study of Noises in Electrical Apparatus.—T. Spooner and J. P. Foltz. (*Journ. Am. I.E.E.*, March, 1929, V. 48, pp. 199–202.)

Progress in Technical Acoustics in Germany in 1928.—W. Wagner. (*E.N.T.*, March, 1929, V. 6, pp. 119–120.)

PHOTOTELEGRAPHY AND TELEVISION.

Picture Telegraphy.—(German Patent 467977, Lorenz, published 3rd November, 1928.)

Coloured paper covered with a thin layer (0.001–0.003 mm.) of wax is used for recording; a very small movement of armature or diaphragm can cause the cutting away of the wax to reveal the coloured background.

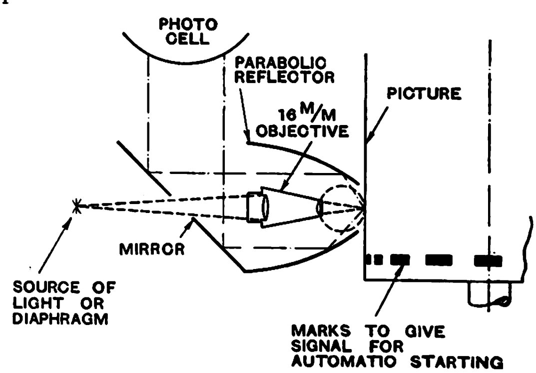
Facsimile Picture Transmission.—V. Zworykin. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 536–550.)

Author's summary :—"A facsimile picture-transmitting system is described. The chief object of the design of this system was to produce a simple, rugged apparatus for practical usage, which would not require the attention of a skilled operator. The system does not require a special preparation of the original, and the receiver records the copy directly on the photographic paper.

"The usually delicate problem of photo-cell current amplification has been simplified to such an extent that only three stages of resistance-coupled amplification suffice between the photo-cell and modulator of the broadcasting station. This was made possible through the design of a very efficient optical system, which supplies to the photo-cell quite enough light reflected from the picture even though only a small incandescent lamp for illumination is used.

"The synchronising and framing have also been simplified to such a degree that they do not require any special channels or special amplifiers.

"Automatic starting devices obviate the use of any complicated scheme of signal dispatch for starting the apparatus. In spite of the simplicity of operation, it is capable of transmitting a 5 in. by 8 in. picture either in black and white or in half-tone in 48 seconds, or a message at the rate of 630 words per minute over short distances.



"The resulting picture prints are of a quality quite satisfactory for newspaper reproduction and clear facsimile of messages may be made from type-written originals."

The transmitting optical system referred to is shown in the diagram.

Recording is done by a Knowles grid-glow (helium) tube, a discharge of about 15 mA. at 400 v. being sufficient, at the speeds named, to give very satisfactory blackening on the bromide paper used.

Synchronisation is by periodic correction of 70-cycle tuning fork control. A very satisfactory example of the work done by this system is given (transmitted over a short telephone line and a few miles of wireless).

THE COLVERGRAPH: TECHNICAL DETAILS OF A NEW PICTURE RECEIVER.—F. H. Haynes. (*Wireless World*, 27th March, 1929, V. 24, pp. 331–334.)

Special points are:—The mechanism by which the standardised "stop-start" synchronising is performed; this mechanism gives an "accelerated start" which relieves the motor of the starting load, and also provides that the driving and driven pinions are running at the same speed when they mesh; trigger-release relays are done away with, the release-magnet winding being permanently traversed by an insufficient current which the starting signal increases—this is said to give constancy of time of release for varying strength of starting signal due to fading, etc.; the stylus does not travel, and any side-play is in the direction of rotation of the cylinder and not transverse to the image-forming line; a spare cylinder, ready loaded, can be dropped into position over the central drum when one picture is finished.

DER GEGENWÄRTIGE STAND DER BILDTELEGRAPHIE: 3.—DER ELEKTROLYTISCHE QUERSCHREIBER VON TELEFUNKEN. 4.—DIE BILDRUNDFUNKENEMPFÄNGER (The Present Position of Picture Telegraphy: 3.—The Telefunken Electrolytic Transcriber, and 4.—The Picture Broadcast Receiver).—F. Noack. (*Rad. f. Alle*, March and April, 1929, pp. 139–143 and 166–171.)

UN NOUVEAU SYSTÈME DE TÉLÉVISION ET DE TÉLÉCINÉMATOGRAPHIE (A New System of Television and Telecinematography).—L. Thurm. (*QST* Franç., January 1929, pp. 58–59.)

Continuation of article referred to in March Abstracts, p. 157.

SYNCHRONISATION.—(German Patent 469012, Dieckmann and Hell, published 29th November, 1928.)

In the system depending on a periodic correcting-signal, the dislocation liable to be caused by a false signal is avoided by making the correcting-signal a definite series of signals, the correcting mechanism at the receiver functioning only on the arrival of the correct series.

THALLIUM PHOTOELECTRIC CELLS.—L. Rolla. (*Nature*, 9th March, 1929, V. 123, p. 396.)

Rolla states that the procedure described by Majorana and Todesco (March Abstracts, p. 158) was published by him in 1927, has been patented, and has been used successfully by the Italian military authorities.

PHOTOELECTRIC CELLS, AMPLIFICATION, ETC.—See under "Miscellaneous," A Recording Photoelectric Colour Analyser.

CÆSIUM-MAGNESIUM PHOTOELECTRIC CELL.—V. Zworykin and E. D. Wilson. (*Sci. Newsletter*, 2nd March, 1929, V. 15, pp. 133–134.)

A paragraph on this new cell, in which the difficulty in working with cæsium is overcome by the use of magnesium, which binds the cæsium to the walls of the glass bulb. Its sensitivity is higher than that of other cells; its greatest response is to bluish-green light, and its use in television would give an image with colour values closely approaching those of the eye.

MEASUREMENTS AND STANDARDS.

NOTE ON AN APPLICATION OF THE WHIDDINGTON ULTRA-MICROMETER.—H. Lloyd. (*Journ. Scient. Instr.*, March, 1929, V. 6, pp. 81–84.)

The dimensional change which it is required to measure alters the capacity of a condenser, and by a heterodyne method indicates its magnitude. This paper describes certain difficulties encountered when using the arrangement for magnetostriction measurements, and the ways in which these were overcome. The wavelength worked on was about 20 m., and the note was matched with that of a 256 p.p.s. tuning fork. Frequency changes due to the movements of the operator wearing the head telephones were completely obviated by using a loud-speaker movement connected by a glass tube 3 ft. long, at the other end of which was a sensitive telephone ear-piece which acted as an electro-dynamic microphone completely insulated (electrically) from the heterodyne circuits.

A further improvement was made by adjusting the length of this tube to suit the fork frequency, thus making it work as an acoustic filter. The tendency of the two H.F. circuits to pull into synchronism was cured by halving the frequency of the second oscillator, using its second harmonic to beat with the first oscillator. Successful visual indication of tuning was obtained (in the form of Lissajous' figures) by the use of an oscillograph device adapted from a reed type Brown relay, a Pointolite lamp, and a mirror on the tuning fork.

Handley (pp. 84–88) describes methods of mounting the variable condenser to eliminate vibration, and other precautions (in connection with the magnetostriction process) to eliminate temperature variations, etc.

NOTE ON MAGNETOSTRICTION AND ALLIED PHENOMENA.—J. H. Vincent. (*Journ. Scient. Instr.*, March, 1929, V. 6, pp. 89–90.)

The writer points out that Whiddington's ultra-micrometer, as adapted by Lloyd and Handley (see above), should be an ideal tool for future investigations on magnetostriction in diamagnetic substances, Barrett effect (change in volume due to magnetic field) in liquids, Joule effect in glass, etc.

LES VIBRATIONS DU QUARTZ PIÉZOÉLECTRIQUE RENDUES VISIBLES EN LUMIÈRE POLARISÉE (The Vibrations of Piezoelectric Quartz rendered Visible by Polarised Light).—E. P. Tawil. (Summary in *Rev. Gén. de l'Élec.*, 12th January, 1929, V. 25, p. 58.)

The piezoelectric vibrations of a quartz crystal involve compressions and dilatations which modify

the optical properties of the crystal: it changes from a uni-axial to bi-axial condition and *vice versa*. The paper describes a method of rendering visible, by this effect on polarised light, the nodes and antinodes of vibration, however complex in form they may be. Once recorded, these figures enable one to know at once at what frequency the crystal is vibrating. Moreover, the point of greatest clearness of the image indicates the resonance point with great accuracy. Finally, the writer mentions that the phenomenon, which has nothing in common with the Kerr effect, gives a method of modulating a light ray at very high frequencies.

Die Wellenkontrolle der Internationalen Rundspruchunion (The Wave Control of the International Radiotelephony Union).—G. A. Schwaiger. (*Elektrot. u. Masch:bau*, 20th January, 1929, pp. 45–49.)

A description of the methods of the Brussels Control Office.

Standardisation of Frequency.—S. Jimbo. (*Res. Electrot. Lab.*, Tokyo, No. 236, September, 1928, 53 pp.)

In English: a long and detailed account of the setting up of a frequency standard. In the part dealing with the measurement of frequency, the stroboscope, phonic motor and harmonic comparator are discussed, together with various improvements. In another part, tuning fork and quartz-oscillator controlled standards, etc., are dealt with, while a final part considers resonators, with their characteristics and response curves. An extensive bibliography is included.

Some Properties of a Fused Silica Tuning-fork.—E. A. Harrington. (*Journ. Opt. Soc. Am.*, February, 1929, V. 18, pp. 89–95.)

"The logarithmic decrement, the coefficient of damping, and the coefficient of stiffness of a fused silica tuning fork were determined from data obtained from photographic records of the vibrations of the tuning-fork after it had been struck with a pianoforte hammer." The results show that fused silica is a highly suitable material, chiefly owing to its high elasticity, small temperature-effect and invariance with time, its very low coefficient of expansion and the almost negligible effect of damping on its vibration period (less than two parts in a thousand million). The chief objections are: (1) its fragility, whence only a small intensity of sound can be produced by hammering—thus preventing its use as a practical standard of pitch; and (2) the vibrations cannot be maintained electrically without loading the prongs with iron.

The Measurement of the Anode Circuit Impedances and Mutual Conductances of Thermionic Valves.—L. Hartshorn. (*Proc. Phys. Soc.*, 15th February, 1929, V. 41, pp. 114–125.)

Author's Abstract:—"The paper describes the application of the Wheatstone Bridge to the measurement of the anode circuit admittance or impedance, and the mutual conductance of a valve under actual operating conditions. Current of telephonic frequency is used. The measurements can be made for grid bias of any desired value, and both methods can be made direct-reading. The results of measurements made on a few typical valves are given, and it is shown that although both anode circuit resistance and mutual conductance vary very considerably with the grid bias, the product of the two, which gives the voltage factor of the valve, is approximately constant. The anode circuit admittance consists of a conductance associated with a comparatively small capacity, but this capacity is larger than the inter-electrode capacities of the valve when the filament is cold. The increase in the effective values of the inter-electrode capacities is explained by the presence of the space charge, which also has the effects of making these capacities vary with the frequency and of giving them a comparatively high power factor, especially at low frequencies."

Later, the author remarks that circuits for comparatively rough measurements of anode circuit resistance have been described by Barkhausen and Bagally, but for precision work, and especially if the actual impedance or admittance is required, and not merely the resistance, a number of refinements are necessary: these include a Wagner earthing device. In the subsequent discussion, he mentions that what he considers one of the most important conclusions to be drawn from his investigation is that the effective inter-electrode capacities of valves are not simply the same as the corresponding "static" capacities, but that they vary with the position on the characteristic curve of the operating point (V, v), and therefore the resistance of the valve, and also with the frequency. His results show the kind of variation and also its order of magnitude. The method could be applied to high frequencies, provided that suitable bridge components were used and that everything were properly screened: the practical difficulties would be considerable, but not insuperable.

An Extension of the Method of Measuring Inductances and Capacities.—S. Harris. (*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 516–520.)

The substitution method commonly employed for measuring small capacities is shown to be a special case of a more general principle. As other special cases of this principle, methods are presented for simultaneously measuring inductance and capacity when joined in series and when joined in parallel. The cases discussed indicate the method of application of the general principle to any type of measuring or measured circuit.

In a subsequent discussion, R. R. Batcher points out several precautions necessary in applying the methods outlined in the paper.

The Measurement of the Inductances and Effective Resistances of Iron-Cored Coils carrying both Direct and Alternating Current.—L. Hartshorn. (*Journ. Scient. Instr.*, April, 1929, V. 6, pp. 113–115.)

"A method is described for the measurement of the effective inductance and resistance of coils of large self-inductance, which are required to carry

a comparatively large direct current, with a superposed alternating current ripple. Hay's inductance bridge is used, with special arrangements for the independent control and measurement of the A.C. and D.C. components, the avoidance of earth-capacity effects without earth-connecting the D.C. supply, and the elimination of the direct current from the vibration galvanometer used as detector, without losing sensitivity. Typical results are given."

A METHOD FOR THE DETERMINATION OF THE EQUIVALENT RESISTANCE OF AIR-CONDENSERS AT HIGH FREQUENCIES.—G. W. Sutton. (*Proc. Phys. Soc.*, 15th February, 1929, V. 41, pp. 126–134.)

Author's Abstract :—" The losses in air-condensers are divided into two portions, (1) those due to leakage through the solid dielectric, and (2) those due to terminal and plate resistance. A method is developed for measuring each, under conditions such that the other is negligibly small. The limits of the errors to which the methods are liable are discussed and some results of practical measurements are quoted."

The method is based on the similarity between the distribution of the lines of current-flow between two electrodes immersed in a conducting solution and that of the lines of electric force between two insulated and charged surfaces of the same area, shape and relative position (a principle used in the investigation of the electromagnetic field of machines, etc.—*cf.* Hague, May Abstracts, p. 280). In the discussion the author defends his method against various criticisms based on the possible effects of submerging the condenser in an electrolyte. Referring to Dye's results and to Wilmotte's (Abstracts, 1928, p. 644, and 1929, p. 162), he mentions points of difference from his own : he finds the solid insulation losses to have an equivalent resistance very closely proportional to $1/f$, and the remaining losses to be represented by a series resistance rapidly increasing with the frequency (as would be expected if they are ascribable to skin effect).

A LOSS-FREE AIR CONDENSER FOR A.C. BRIDGE WORK.—K. Ogawa. (*Journ. I.E.E., Japan.* December, 1928, pp. 1278–1298.)

The use of earthed screening round the insulators supporting the two series of electrodes has already been described by others, but here the use of such a condenser is particularly recommended for use with an A.C. bridge. Also, being independent of frequency, it can serve as a standard of capacity.

RESONANCE RADIOMETRY.—A. H. Pfund. (*Science*, 18th January, 1929, V. 69, pp. 71–72.)

The limiting sensitivity of any radiometric system is reached when spurious deflections become comparable with real deflections. Beyond this point optical magnification, increased period, etc., are of no avail. An attempt is here most successfully made to reduce the relative effect of spurious disturbances by causing the radiations to be intermittent with a definite period, and to " tune " the entire system to that period. A thermopile was exposed to radiation at intervals of 0.75 sec. by means of a pendulum with a 1.5 sec. period, and was connected to a D'Arsonval galvanometer tuned to 1.5 sec.

A concave mirror on this projected the image of a coarse grid on to a second, similar grid, this latter being " split " centrally so that the image of the first grid—when in motion—increased the amount of light transmitted on one side and decreased that on the other. By means of a split lens, the light passing the second grid was brought to two foci on the junctions of a compensating thermopile (later, sensitivity was increased 1,000 times by replacing this by a photoelectric cell and amplifier). This controlled a second galvanometer also tuned to 1.5 sec. High sensitivity, combined with a high degree of immunity from disturbances, was obtained.

SUR UNE MÉTHODE DE MESURE DE TRÈS FAIBLES COURANTS ÉLECTRIQUES, MÉTHODE DITE D'ÉLECTROMÉTRIE TACHYMÉTRIQUE (The " Tachometric " Method of Measuring Very Small Electric Currents).—C. Guilbert. (*Comptes Rendus*, 18th March, 1929, V. 188, pp. 861–863.)

The writer calculates that by this method currents of the order of 10^{-18} ampere can be measured. It depends on noting the r.p.m. of a motor which in its rotation successively charges a very small condenser to a fixed voltage and discharges it into an electrometer ; the motor speed being adjusted so that the charges thus given compensate for the charge which is being lost from the electrometer by reason of the current to be measured ; so that the electrometer is kept at a constant deflection.

DEUX EXEMPLES DE MONTAGES QUI FONT INTERVENIR LA VARIATION DES CARACTÉRISTIQUES D'UN APPARAIL RÉCEPTEUR OU DE MESURE (Two Examples of Methods of Connection which introduce Variation of the Characteristics of a Receiving or Measuring Instrument).—L. Cagniard. (*L'Onde Élec.*, February, 1929, V. 8, pp. 68–76.)

Second part of the paper referred to in Abstracts, 1928, V. 5, p. 523. It shows how a quadrant electrometer can be used as the indicating instrument in a Wheatstone bridge supplied with H.F. current, and how its use results in an arrangement of extraordinary sensitivity and accuracy for the measurement of capacities, inductances, etc. A change in capacity of the order of 1 in a million or even more can be measured.

MEASUREMENT OF ULTRA-RADIO FREQUENCIES BY STANDING WAVES ON WIRES AND ITS COMPARISON WITH THAT BY MULTIVIBRATOR SYSTEM.—S. Ishikawa. (*Res. Electrot. Lab., Tokyo*, November, 1928, No. 242, 34 pp.)

In Japanese. To test whether Lecher wire measurements could be relied on (after applying Hund's correction factor) a comparison with Multivibrator results was made. It was found that while the latter system had an accuracy of about 0.003 per cent., the parallel wire method had an accuracy about a tenth of this ; direct comparison showed that the latter system always gave

higher values than the former, by about 0.1 per cent. The tests were on a narrow band round 25 m.

Use of the modified Belfils Bridge for the Measurement of the Irregularity of a Voltage not strictly Continuous.—C. Chiodi. (*L'Elettrotec.*, 5th October, 1928, V. 15, pp. 757–764.)

The author has applied this bridge very successfully to such investigations as that of the current through a mercury vapour rectifier, and finds it the easiest of all methods so far known.

Thermionic Valve Potentiometer for E.M.F. Measurements.—H. M. Partridge. (Summary in *Nature*, 20th April, 1929, V. 123, pp. 620–621; from *J. Am. Chem. Soc.*, January.)

An arrangement of a tetrode and a triode is described (the latter acting as an amplifier giving greater sensitivity) which is said to be independent of constancy of the valve characteristics and of the filament and plate potentials. Its action is essentially electrostatic; no calibration of the valves is necessary, the E.M.F. being read directly from a voltmeter in the grid circuit of the first valve.

Eine einfache Kompensationsschaltung zur Messung der Kapazität und des dielektrischen Verlustwinkels von Kondensatoren und Kabeln (A Simple Compensation Circuit for the Measurement of Capacity and Dielectric Loss Angle of Condensers and Cables).—W. Geyger. (*Arch. f. Elektrot.*, 8th April, 1929, V. 21, pp. 529–534.)

Contacts in Apparatus for Measuring Electrical Resistivity.—J. L. Haughton. (*Journ. Scient. Instr.*, April, 1929, V. 6, pp. 120–124.)

"In the measurement of electrical resistances by means of potential drop methods, four contacts are required. Methods for making these contacts with the resistance to be measured, both in the cold and at high temperatures, are discussed, and types of contacts suitable for different requirements are specified."

A Direct-Reading Instrument for Measuring Low Resistances.—L. H. Bainbridge-Bell. (*Journ. Scient. Instr.*, April, 1929, V. 6, pp. 139–140.)

This instrument was developed in the course of experiments on mercury contacts. The requirements were that no damage to the indicating instrument should result if the resistance under test suddenly became infinite, and that the current flowing in the device under test should be limited to 1 ampere.

A New A.C. Microammeter.—(*Journ. Scient. Instr.*, April, 1929, V. 6, pp. 137–138.)

A Ferranti moving-coil, copper-oxide rectifier instrument: with useful frequency-range 20-6,000 cycles, reading to 750 microamperes with a scale nearly linear from about 100 microamperes upwards.

A Valve Potentiometer for High and Low Frequency Measurements.—(*Journ. Scient. Instr.*, April, 1929, V. 6, pp. 135–137.)

A Tinsley instrument "designed to provide a means of measuring small high-frequency voltages with the same facility that direct current measurements can be made with the potentiometer."

On the Measurement of the Dielectric Constants of Liquids, with a Determination of the Dielectric Constant of Benzene.—L. Hartshorn and D. A. Oliver. (*Proc. Roy. Soc.*, 6th April, 1929, V. 123 A, pp. 664–685.)

Mutual Inductance and Torque Between Two Concentric Solenoids.—C. Snow. (*Bur. of Stds. J. of Res.*, November, 1928, V. 1, No. 5, pp. 685–699.)

Formulæ are derived for the mutual inductance and torque, for any angle between axes, presuming strip windings, so that the solenoids constitute current sheets; correction terms are obtained to allow for finite cross section and discrete nature in the two windings.

Simple Inductance Formulas for Radio Coils.—(*Proc. Inst. Rad. Eng.*, March, 1929, V. 17, pp. 580–582.)

A discussion on Wheeler's paper dealt with in January Abstracts, p. 49.

Eine verallgemeinerte Methode zur Berechnung der Induktivitäten ebener Figuren beliebiger Form (A General Method for the Calculation of the Inductance of Plane Figures of any Shape).—V. J. Bashenoff. (*E.N.T.*, January, 1929, V. 6, pp. 22–40.)

High Voltage Measurement.—J. S. Carroll and B. Cozzens. (*Journ. Am. I.E.E.*, December, 1928, V. 47, pp. 892–896.)

A new method is described of measuring high voltages, in which the current through a water resistance is recorded on an oscillograph. Over a million volts to earth have been measured with an accuracy believed to be better than 2 per cent. The calibration of a metre-sphere gap was determined for voltages up to 1,100 kv.; also the arc-over voltages for point gaps, for distances up to 30 ft.

A Simple Earthing Switch for Small Electrometers.—G. B. Moss. (*Journ. Scient. Instr.*, April, 1929, V. 6, pp. 124–126.)

A suitably shielded switch, adding little to the capacity of the instrument, and worked by a bulb and tube such as are used for photographic shutters.

Über die Magnetostriktion der Eiseneinkristalle (The Magnetostriction of a Single Crystal of Iron).—N. Akulov. (*Zeitschr. f. Phys.*, 4th December, 1928, V. 52, No. 5/6, pp. 389–405.)

The general formulæ here arrived at agree well with the experimental results of Honda and Mashiyama.

UNTERSUCHUNGEN ÜBER DIE ANFANGSSTROME IM QUARTZ (Investigation of the Initial Current in Quartz).—A. D. Goldhammer. (*Zeitschr. f. Phys.*, 31st December, 1928, V. 52, No. 9/10, pp. 708–725.)

NEUE AUSFÜHRUNGEN VON FERNMESSANLAGEN (New Developments in the Distant Reading of Meters, etc.).—W. Stern. (*E.T.Z.*, 7th March, 1929, pp. 351–353.)

A description of the latest developments of the Telewatt system.

DECIBEL—THE NAME FOR THE TRANSMISSION-UNIT.—W. H. Martin. (*Bell Tech. Journ.*, January, 1929, V. 8, pp. 1–2.)

The European International Advisory Committee has recommended to the various European telephone administrations that they adopt either the decimal or the napierian unit and designate them the "bel" and "neper" respectively. The Bell System has adopted the name "decibel" for the old T.U. (*see* Herd, February Abstracts, p. 111). It will be represented by the abbreviation "db."

UNITS OF ELECTRICAL TRANSMISSION.—J. W. Horton. (*Rad. Engineering*, February, 1929. V. 9, p. 31.)

An article starting with the old "800 cycle mile" and ending with the new "decibel" (here spelt "decibell," thus preserving more clearly the derivation from Graham Bell). It is mentioned that "in high quality broadcast transmission, a power level of 0.006 watt has been arbitrarily chosen as zero level. Thus when we say that an amplifier is capable of delivering a 'plus 10 db level' we mean that it is capable of delivering 0.06 watt."

A SONIC INTERFEROMETER FOR MEASURING COMPRESSIONAL VELOCITIES IN LIQUIDS: A PRECISION METHOD.—A. L. Loomis and J. C. Hubbard. (*Journ. Opt. Soc. Am.*, October, 1928, Part I, V. 17, pp. 295–307.)

The quartz plate is driven at 500,000 cycles/sec. At such a frequency the wavelength in the liquid is small compared with the diameter of the vibrating plate, and it is found that under this condition the measured velocity is independent—to a very high degree of precision—of the dimensions and material of the containing vessel (other methods, using audible frequencies, were vitiated by elastic reaction of the walls, etc.). Very consistent curves are given showing the velocity in water, salt solutions, and mercury, as a function of temperature: and another showing the velocity in salt solution as a function of the percentage of salt.

A MEASUREMENT OF RADIATION AT ABOUT 5μ.—K. E. Gould. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 198–206.)

A description of the methods and apparatus employed in certain measurements of infra-red radiations by means of a linear thermopile. The latter was constructed by a somewhat new process; the temperature-control methods, though not new, are specially adapted to the particular purpose.

SUBSIDIARY APPARATUS AND MATERIALS.

ARRANGEMENT FOR OBTAINING AN ALTERNATING CURRENT OF CONSTANT VOLTAGE FROM AN A.C. SUPPLY OF VARIABLE VOLTAGE.—(*French Patent*, 646,957, Brown Boveri et Cie, pub. 19th November, 1928.)

The primaries of two transformers are connected in series across the mains. One transformer has a saturated, the other an unsaturated core. Their secondaries are in series but in opposition, and if these windings are properly chosen the voltage across them remains constant for considerable variations in the voltage across the mains (test has shown that it is also very little affected by variations of frequency). The constancy can be increased still further by the insertion of an ohmic resistance in the primary circuit, and is so good that the device is specially suitable for use with those vacuum-measuring instruments which are heated by A.C.

TEMPERATURE CONTROL APPARATUS.—L. A. Richards. (*Journ. Opt. Soc. Am.*, February, 1929, V. 18, pp. 131–137.)

A detailed description of easily-constructed apparatus for use in an air or water bath. A thermo-regulator, utilising the thermal expansion of methyl alcohol or preferably ether, controls the current through the nichrome resistance wire stretched in the air chamber. A pencil-type electric heater consisting of nichrome wire wound on porcelain, encased in a 14-inch brass jacket, is used in the case of a water bath. (*Cf.* Jarvis and Black, Abstracts, 1929, p. 163.)

A PRECISION REGULATOR FOR ALTERNATING VOLTAGE.—H. M. Stoller and J. R. Power. (*Jour. Am. I.E.E.*, February, 1929, V. 48, pp. 110–113.)

A small transformer in one line adds or substracts the voltage required to compensate for fluctuations, its saturation being controlled by a valve-circuit acting through an inductance bridge. Output voltage can be kept constant to within 0.03 per cent. for an input voltage range of 10 per cent. and a load range of from zero to full load. The control valve is a diode, in which a 0.1 per cent. change in filament current will produce a 2 per cent. change in anode current.

CONVERTISSEUR DE COURANT ÉLECTRIQUE DE GRANDE PUISSANCE À ÉTINCELLE PILOTE (High Power Current Converter with Pilot Spark).—P. Toulon. (*Rev. Gén. de l'Elec.*, 30th March and 6th April, 1929, V. 25, pp. 477–482 and 518–526.)

An authoritative paper on the Toulon "converter," which can be used "not only to rectify an alternating current but also to regulate voltage, current and frequency: all these results being obtained with entirely stationary apparatus." It depends on the rectifying properties of a circuit connected to one pole of an arc and to a conductor placed in the arc itself. The second part of the paper includes oscillograms of the work of such a converter, and a description and illustrations of

a six-phase model, for 100 kw. at 600 v. The paper ends with an enumeration of the advantages of these converters over large mercury vapour rectifiers: but the last words are a warning that the former will never come into general use until a metal is discovered resistant enough to produce a life equal to that of the latter.

A THERMIONIC-VALVE TYPE CLOSE VOLTAGE REGULATOR.—F. C. Turner. (*Engineering*, 21st October, 1927, V. 124, pp. 537–538.)

Voltage from a 15 kw., 200 v., D.C. generator driven off the mains was kept constant within ± 0.03 v. by a two-valve circuit, or within 0.3 v. by a single valve circuit. The method depends on the fact that whereas a variation from 199 to 201 v. is small, a change from -1 through 0 to $+1$ v. is a different matter; this is made use of by means of a balancing battery (practically on open circuit) and a three-electrode valve or valves, whose filament and anode supply is provided by the generator itself.

THE APPLICATION OF THE PROPERTIES OF THIN METAL FILMS TO THE MANUFACTURE OF DELICATE ELECTRIC FUSES.—(*Journ. Scient. Instr.*, March, 1929, V. 6, pp. 102–104.)

Fuses which blow at currents between 5 and several hundred milliamperes are now being manufactured. The time of operation of a 80 mA. fuse is less than one thousandth of a second. The paper deals with these fuses and with the superiority of their performance over what might be expected from their dimensions and the thermal properties of the metal—gold—composing them. The final section deals with the preparation of thin metal film, and some performances.

LA THÉORIE ÉLECTRONIQUE ET LE MÉCANISME DE L'EFFET DE SOUPAPE DANS LES CELLULES ÉLECTROLYTIQUES (The Electronic Theory and the Mechanism of the Valve Effect of Electrolytic Cells).—R. Audubert. (*Rev. Gén. de l'Élec.*, 17th November, 1928, V. 24, pp. 737–740.)

The behaviour of these rectifiers is here said to conform with the electrochemical theory of oxidation-reduction and *not* with the electronic theory. The arguments, however, are refuted by Dubar (*ibid.*, 16th March, 1929, p. 399), but Audubert continues the argument on p. 401.

A NEW TYPE OF RECTIFIER TUBE FOR AMATEUR USE.—O. W. Pike and H. T. Maser. (*QST*, February, 1929, V. 13, pp. 20–22.)

The UX-866 is a new hot-cathode mercury vapour rectifier differing from the usual mercury arc tube in (1) its low temperature operation, resulting in high breakdown reverse voltage; and (2) that the rectified current is made up of electrons emitted from a coated ribbon filament. Absence of starting mechanism, low voltage drop (only about 15 v.), and possibility of series connection are some of its advantages. Its rating is stated in terms of its fundamental limits: namely, the maximum peak inverse voltage (5,000 v.), and the peak current through the tube (0.6 amp.).

ALTERNATING CURRENT RECTIFICATION AS APPLIED TO RADIO. Part I.—R. J. Kryter. (*QST*, April, 1929, V. 13, pp. 33–37, 39, 50).

THE PREVENTION OF IONISATION IN PAPER DIELECTRICS.—S. G. Brown and P. A. Sporing. (*Nature*, 23rd March, 1929, V. 123, p. 472.)

Summary of a lecture before the *I.E.E.* Discussing the breakdown of paper condensers after about a year's service, and the similar behaviour of cables insulated with impregnated paper, it is stated that there is considerable evidence that this is due to the presence of air bubbles in the dielectric. The authors show by theory and experiment the incorrectness of the usual assumption that if the dielectric is worked below the "critical" or "ionisation" voltage (at which the power taken by the cable suddenly begins to increase rapidly) then no ionisation of the air can take place. What is true is that however close together two electrodes are in air at atmospheric pressure, ionisation does not ensue unless the voltage exceeds (approximately) 330 v. The application of this fact to the design of condensers is described: either many thin sections are built up in series so that the voltage across any one section does not exceed that required for ionisation, or isolated conducting layers (interleaves) are placed in the dielectric.

DIELECTRIC PROPERTIES OF THE SULPHUR-RUBBER COMBINATIONS.—S. Kimura, T. Aizawa and T. Takeuchi. (*Journ. I.E.E., Japan*, December, 1928, pp. 1274–1279.)

The conclusions of Curtis and his Bureau of Standards collaborators are condemned on the ground that all their measurements were taken at one temperature; the writers describe their own tests between 0° and 180°C.

LEITSÄTZE FUR DIE PRÜFUNG VON GLIMMERERZEUGNISSEN (Test Specifications for Mica Products).—(*E.T.Z.*, 18th April, 1929, pp. 586–588.)

Proposals of the Insulating Material Committee of the VDE.

THE MECHANICAL PROPERTIES OF MICA. (*World Power*, January, 1928, V. 11, pp. 32–34.)

Results of the tests carried out for the Electrical Research Association with the object of classifying micas derived from various sources.

APPLICATION DU DÉMULTIPLICATEUR STATIQUE DE FRÉQUENCE À L'OSCILLOGRAPHE CATHODIQUE. (Application of the Static Frequency Transformer to the Cathode-ray Oscillograph).—F. Vecchiacchi. (*L'Elettrotec.*, 25th October, 1928, V. 15, pp. 805–814. Summary in *Rev. Gén. de l'Élec.*, January, 1929, V. 25, pp. 19D–20D.)

To produce his time base the writer uses a current of frequency which is an exact sub-multiple of that of the current or potential to be analysed, thus producing a figure which can be conveniently examined or photographed. Mechanical (rotating commutator) methods will work for an analysed

frequency up to 1,000 p.s. (assuming a frequency ratio of 20), but valve methods extend the scope to high frequencies. The ordinary valve method of frequency-multiplication is applicable over a wide range of frequencies, but certain advantages (for frequencies over 100,000) are offered by the method of using a triode as a rectifier to charge up a condenser which discharges itself after a certain number of periods. The writer suggests that the method would be of great use in a new study of the functioning of triodes—for very high frequencies a Wood or Dufour type oscillograph taking the place of the Western.

Lenard Ray Tube with Glass Window.—C. M. Slack. (*Journ. Opt. Soc. Am.*, February, 1929, V. 18, pp. 123–126.)

See March Abstracts, p. 163 : Cathode Rays as a Laboratory Tool.

Ein Zeitkipper für den Kathodenoszillographen (A Time-switch for Cathode-ray Oscillographs).—W. Rogowski and O. Wolff. (*Arch. f. Elektrot.*, 8th April, 1929, V. 21, pp. 645–654.)

A starting arrangement for oscillographs used for recording uncontrolled phenomena is described which the writers consider a desirable substitute for Gabor's switching-relay, chiefly on the grounds of simplicity, reliability, and small lag (as low as 10^{-8} sec.). A condenser is kept charged to a voltage just insufficient to break down a spark gap. The incoming surge induces just enough extra potential to produce the breakdown; the condenser discharges and, in so doing, starts the recording. By a suitable arrangement the whole device re-sets itself for the next record.

Aussenaufnahmen von Kathodenstrahloszillogrammen durch Lenardfenster (External Recording of C-R-Oscillograms through a Lenard Window).—M. Knoll and -.Stoerk. (*Zeitschr. f. tech. Phys.*, January, 1929, pp. 28–30).

A photographic recording-speed of 20 m./sec., and a visual recording-speed of 1.4 km./sec., have already been successfully obtained.

Über eine neue erschütterungsfreie Aufstellung für empfindliche Messinstrumente (A New Vibration-free Mounting for Sensitive Measuring Instruments).—R. Müller. (*Ann. der Physik*, 12th March, 1929, Series 5, V. 1, No. 5, pp. 613–656.)

Oscillographs for Recording Transient Phenomena.—W. A. Marrison. (*Journ. Am.I.E.E.*, April, 1929, V. 48, pp. 261–264.)

Two instruments (both of the moving iron balanced-armature type) are described :—the "polar" oscillograph for recording very short transients on a rotating disc of film, and the "continuous-film" oscillograph for making long continuous records. Examples of the work of both types are given. A system of operation is described in which two polar and one c.f. type instruments are used together for studying transients likely to occur at any time during a long period.

The Construction and Calibration of a Sensitive Form of Pirani Gauge for the Measurement of High Vacua.—L. F. Stanley. (*Proc. Phys. Soc.*, 15th April, 1929, V. 41, pp. 194–203.)

The instrument described is capable of measuring pressures within the range 2×10^{-3} and 4×10^{-6} mm.

The Behaviour of Glass as a Dielectric in Alternating Current Circuits: Part II. The Effect of Frequency and of Temperature upon the Power Loss.—L. S. McDowell and H. L. Begeman. (*Phys. Review*, January, 1929, V. 33, pp. 55–65.)

A Test Condenser for Extra High Tensions.—R. Vieweg and H. Schering. (*Zeitschr. f. tech. Phys.*, November, 1928, pp. 442–445.)

The full paper, a summary of which was referred to in March Abstracts, p. 163.

Über die Phasenlage des Magnetisierungsstromes des Lufttransformatoren (The Phase Conditions of the Magnetising Current of Air Core Transformers).—G. Hauffe. (*Zeitschr. f. tech. Phys.*, February, 1929, pp. 66–67.)

A mathematical treatment, resulting in the proof that for toroidal air-core transformers, where the primary winding is completely inside the secondary, the magnetising current is always in phase with the flux in the inner toroidal coil.

Le Stroborama, nouvel Appareil Stroboscopique à grand Éclairage (The Stroborama, a new Stroboscope with High Illumination).—L. and A. Seguin. (Summary in *Rev. Gén. de l'Élec.*, 23rd February, 1929, V. 25, p. 62D.)

A rotating contact, of variable speed, combined with a condenser and spark gap, acts as a kind of shunting relay and governs the current through a neon tube. Various commercial applications are mentioned.

Eine einfache Anordnung für stroboskopische Untersuchungen (A Simple Arrangement for Stroboscopic Investigations).—H. E. Linckh and R. Vieweg. (*Zeitschr. f. Inst:kde.*, No. 9, 1928, V. 48, pp. 416–421.)

An electrical arrangement is described, on the "flash" method, in which the observation-frequency is automatically controlled by the frequency of the observed process. The flashes of the glow-lamp are produced inductively by an auxiliary voltage, and they are very much brighter than those produced by the sine-wave A.C. so often used.

Spiral Springs of Quartz.—K. Šliūpas. (*Technika, Lithuania*, No. 3, 1927.)

An apparatus is described for the manufacture of these springs by a direct method, which avoids the formation of a compression on the inside and an extension on the outside such as are obtained with the indirect methods.

THE ALUMINIUM ELECTROLYTIC CONDENSER.—H. O. Siegmund. (*Bell Tech. Journ.*, January, 1929, V. 8, pp. 41–63.)

AN AUTOMATIC MERCURY STILL.—F. L. Robeson. (*Journ. Opt. Soc. Am.*, January, 1929, V. 18, pp. 72–74.)

This new form of vacuum mercury still is easily made from standard laboratory glassware, starts and stops automatically, and needs very little attention. The power required is 90 w. for an output of 100 gms. of mercury per hour. Another type of still is described by K. Hickman (pp. 62–68).

DRALOWID-VARIATOR (The "Dralowid" Variable Resistance).—(*E.T.Z.*, 28th February, 1929, p. 329.)

The system here adopted reduces resistance by connecting more resistances in parallel.

ÜBER EINEN NEUEN KOHLEWIDERSTAND (A New Carbon Resistance).—C. A. Hartmann and H. Dossmann. (*Zeitschr. f. tech. Phys.*, November, 1928, pp. 434–438.)

The complete paper, a summary of which was referred to in April Abstracts.

CHOKE-COILS WITH SATURATED IRON CORES.—F. Ollendorff. (*Archiv. f. Elektrot.*, 22nd October, 1928, V. 21, pp. 6–24.)

By replacing the saturation curve by a closely approximate hyperbolic sine function, problems of saturated-core chokes can be dealt with by the use of elliptic and Bessel functions.

ÜBER DEN EINFLUSS DER KORNGRÖSSE AUF DIE MAGNETISCHEN EIGENSCHAFTEN (On the Influence of Grain Size on the Magnetic Properties).—O. v. Auwers. (*Zeitschr. f. tech. Phys.*, December, 1928, pp. 475–478.)

Conflicting results of various workers are reconciled by the writer's theory—based on the tests described—that the effect of grain size is merely a secondary effect due to the amount of deleterious matter—oxide, carbide, etc.—varying with the grain size. If these substances are absent, through purity, or are removed by suitable heat treatment, the effect is no longer present.

LES REDRESSEURS À VALVE THERMO-IONIQUE (Thermionic Rectifiers).—*Génie Civil*, 9th February, 1929, V. 94, p. 155.)

In a summary of an article in *L'Industrie Élec.*, oscillograph tests are mentioned which indicate that the smoothing capacities and inductances usually employed are quite inadequate.

ERFAHRUNGEN MIT DEM TANTALGLEICHRICHTER (Results with the Tantalum Rectifier).—F. Bödigheimer. (*Rad. f. Alle*, January, 1929, pp. 13–16.)

An article in praise of this form of accumulator-charging rectifier, claimed to be the only one free from defects of one kind or another.

LES REDRESSEURS DE COURANTS ALTERNATIFS (A.C. Rectifiers).—*Génie Civil*, 2nd February, 1929, V. 94, pp. 123–124.)

Summary of a paper by Soulier, dealing with (*a*) electrolytic valves; chief difficulties are temperature-rise and the presence of impurities; the use of tantalum and lead as electrodes and the addition of iron sulphate in the electrolyte appears to give a cell which will function continuously for small powers, as also will Audubert's silicium rectifier (Abstracts, 1928, V. 5, p. 404); (*b*) arc rectifiers; notably the mercury vapour rectifiers, but also the Murphy and the recent Toulon rectifier, the latter consisting of two electrodes a few millimetres apart in a gas, connected through a resistance to the source of A.C.; a cathodic spot is formed on one electrode (either by a momentary contact or by a very short over-voltage); for high powers the electrodes are water-cooled; (*c*) rarified gas rectifiers: Villard's aluminium spiral—straight-wire cell, a laboratory instrument for rectifying currents of a few milliamperes at 10,000–60,000 v., requiring regeneration after some hours' working; (*d*) hot-filament rectifiers, *e.g.*, Tungar, up to 1 kw.; (*e*) electronic rectifiers such as the "colloid valve" of André, the "Sulfotron" and the oxide rectifiers; and (*f*) the mechanical arrangements—vibrating blades with water or glycerine damping, and the Soulier type resembling an electricity meter; polarised relay rectifiers, derived from the Baudot relay, of several types; rotary forms, capable of design for large powers; though these do not seem to have made their way in opposition to the mercury vapour rectifiers.

METAL TO GLASS ELECTRODE SEALS.—D. R. Barber. (*Journ. Scient. Instr.*, April 1929, V. 6, pp. 138–139.)

JOINING GLASS TO METAL BY SOLDERING. (*Scient. Amer.*, April, 1929, pp. 352—354.)

Various methods are mentioned of obtaining the thin metal film on the glass, which is the necessary preliminary step.

COMPRESSED POWDERED PERMALLOY: MANUFACTURE AND MAGNETIC PROPERTIES.—W. J. Shackelton and I. G. Barber. (*Journ. Am.I.E.E.*, April, 1928, V. 47, pp. 429–436; also *Bell Tel. Lab. Reprint, B.* 328.)

THE INFLUENCE OF GLAZE ON INSULATOR STRENGTH.—D. H. Rowland. (*Gen. Elec. Review*, March, 1929, V. 32, pp. 136–138.)

STATIONS, DESIGN AND OPERATION.

HORAIRES DES ÉMISSIONS RADIOTÉLÉGRAPHIQUES ET RADIOTÉLÉPHONIQUES DE LA STATION DE LA TOUR EIFFEL (The Daily Programme of Telegraphic and Telephonic Transmissions from the Eiffel Tower Station). (*Rev. Gén. de l'Élec.*, 12th January, 1929, V. 25, pp. 11B–12B.)

This programme, however, would appear to be modified by an announcement (*ibid.*, 19th January, pp. 18B–19B) in which it is stated, in the course of

an explanation of the reasons for the change of wavelength from 2,650 m. to 1,485 m., that owing to protests from the Parisians against interference the *broadcasting* from the Eiffel Tower Station will cease at once.

DIE NEUEN WELLENLÄNGEN (The New Wavelengths). (*Rad. f. Alle*, March, 1929, pp. 123–129.)

A table of the new (1929) wavelengths of the European broadcasting stations. Identification notes are added in many cases. In the next (April) issue is given a table of the most important short-wave stations of the world (14.75–90 m.).

ÉMISSION RADIOTÉLÉPHONIQUE DE RENSEIGNEMENTS GÉOPHYSIQUES ET ASTROPHYSIQUES (Radiotelephonic Transmission of Geophysical and Astrophysical Information). (*L'Onde Élec.*, January, 1929, V. 8, p. iii.)

A note on the Eiffel Tower geophysical and astrophysical bulletin, appended since 1st December, 1928, to the usual meteorological report, under the auspices of the U.R.S.I.

WELTRUNDFUNKVEREIN (World Broadcasting Union). (*E.T.Z.*, 18th April, 1929, p. 577.)

A paragraph, with a list of the organisations concerned, on the International Union of Radiotelephony.

THE FUTURE OF WIRELESS BROADCASTING.—J. C. W. Reith. (*Discovery*, February, 1929, V. 10, pp. 37–39.)

An article by the Director-General of the B.B.C. on the solution of present difficulties caused by the fact that there are to-day nearly 300 stations in Europe trying to broadcast on a wave band just sufficient for 100.

SELECTIVITY AND THE REGIONAL SCHEME: DISCUSSION.—G. Leslie and others. (*Journ. Inst. Wireless Tech.*, September, 1928, V. 2, pp. 19–34.)

THE ARMY-AMATEUR RADIO SYSTEM IS REVISED. (*QST*, March, 1929, V. 13, pp. 21–25.)

An article on the recent revision of the Army-Amateur System, the structure of relations between the transmitting amateurs of the American Radio Relay League and the Signal Corps of the U.S. Army.

PROGRESS OF BROADCASTING (SOUND AND PICTURE) IN GERMANY IN 1928.—W. Wagner. (*E.N.T.*, March, 1929, V. 6, pp. 118–119; part of a long paper on Progress in Electrical Communication.)

PROGRESS OF WIRELESS TELEGRAPHY AND TELEPHONY IN GERMANY IN 1928.—W. Wagner. (See above, pp. 117–119.)

Special mention is made of ultra-short wave (e.g., 30 cm.) valves recently developed and soon to be put on the market. One type, designed by Habann, has—under the simultaneous influence of magnetic and electric fields—a falling current-voltage characteristic and thus possesses the property of generating oscillations without the use of reaction.

TRASMETTITORI A ONDA CORTA PER I COLLEGAMENTI TRANSOCEANICI DELLA ITALO RADIO (Short Wave Transmitters, for Transoceanic Communication, of the Italo Radio Company).—V. Gori. (*L'Elettrotec.*, 25th February, 1929, V. 16, pp. 137–142.)

An authoritative technical outline.

WORLD-WIDE TELEPHONY: SUCCESSFUL SHORT-WAVE SERVICE BETWEEN HOLLAND AND JAVA.—A. de Haas. (*Wireless World*, 20th March, 1929, V. 24, pp. 313–316.)

The text of this article deals exclusively with the anti-fading receiving equipment used at the Java end. As many as six receiving sets, each with its directive aerial, are used to provide a combined L.F. output. Automatic volume control is also employed.

MODERN PRACTICE IN HIGH-FREQUENCY RADIOTELEPHONY.—R. A. Hull. (*QST*, April, 1929, V. 13, pp. 8–22.)

"A discussion of improved methods which virtually revolutionise amateur telephone transmission." Very complete details of a set embodying these are given.

GENERAL PHYSICAL ARTICLES.

THE CHANGE OF ELECTRICAL CONDUCTIVITY IN STRONG MAGNETIC FIELDS (Two Parts).—P. Kapitza. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A, pp. 292–372.)

The first part contains a description of improvements on the previous methods (Abstracts, 1928, V. 5, p. 469; bismuth crystals only) and a systematic account of the experiments on a large number of other metals. The second part gives a theoretical generalisation of the results, and a discussion of their bearing on the present theory of metallic conductivity.

SOME CHARACTERISTICS OF THE DISCHARGE BETWEEN COLD ELECTRODES IN VACUUM.—A. W. Hull and E. E. Burger. (*Phys. Review*, June, 1928, V. 31, p. 1121.)

Fixed tungsten electrodes were used at 2 mm. gap in a good vacuum, and heavy discharges from a transformer or charged condenser were passed. Current-time and voltage-time cathode ray oscillograms showed that the discharge began as a purely electron discharge, but in less than 10^{-7} sec. passed into a tungsten vapour arc, with an arc voltage of less than 1,000 v. for 20,000 A. discharge current. Other results are mentioned.

A THEORY OF THE ELECTRIC DISCHARGE THROUGH GASES.—P. M. Morse. (*Phys. Review*, June, 1928, V. 31, pp. 1003–1017.)

Three general differential equations are set up which determine the average behaviour of a discharge of electricity through a gas. Approximate

solutions giving the electric field and the concentration of electrons and positive ions at any distance from the cathode are found for several ranges of value of field. The various phenomena of the process (*e.g.* the electric arc: striations in the positive column of a glow discharge) are explained in terms of these equations.

DIE ROLLE DES POSITIVEN IONS BEI DER SELBSTTÄTIGEN ENTLADUNG IN LUFT (The Rôle of the Positive Ion in the Spontaneous Discharge in Air).—W. Muller. (*Zeitschr. f. Phys.* 14th May, 1928, V. 48, pp. 624–646.)

Experiments are described to decide whether the activity of the positive ions is exerted in the form of shock-ionisation in the gas or by setting free electrons at the cathode. The second alternative is deduced to be correct.

THE TIME LAG OF THE SPARK GAP.—J. W. Beams. (*Journ. Franklin Inst.* December, 1928, V. 206, pp. 809–815.)

A new method of measuring the time lag is described and some of the lags for sparks in air at atmospheric pressure have been recorded. The field strength used ranged from 60,000 to 400,000 v/cm., with as steep wave-fronts as could be obtained. The method (involving a Kerr cell) enables one to measure very short lags occurring with high field strengths, and the measuring device itself does not affect the results.

THE EFFECT OF SUPERIMPOSED MAGNETIC FIELDS ON DIELECTRIC LOSSES AND ELECTRIC BREAKDOWN STRENGTH.—A. Monkhouse. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part I, pp. 83–93.)

Both factors are seriously affected by the superimposed fields. A theoretical explanation by Smouroff is mentioned.

SPECTRAL EXCITATION BY RECOMBINATION IN THE ELECTRIC ARC.—J. M. Dewey. (*Phys. Review*, December, 1928, V. 32, No. 6, pp. 918–921.)

Recent measurements of electron velocities in arcs have made it probable that most of the light in the negative glow is a result of recombination of positive ions and electrons. Since the velocities of the positive ions are high, Compton suggested that the lines of the negative glow should show Döppler broadening corresponding to these velocities. Evidence of this broadening is here presented. Results obtained can be explained on the assumption that all the light of the negative glow results from recombination of ions having a temperature about one-tenth that of the electrons.

THE POSSIBILITY OF DETECTING INDIVIDUAL COSMIC RAYS.—W. F. G. Swann. (*Journ. Franklin Inst.*, December, 1928, V. 206, pp. 771–778.)

The writer's object is to show that in view of the enormous energy available for ionisation in a single cosmic ray, and of the relatively small number of ions produced per second by the rays in a vessel of moderate size, the ionisation produced should occur in spurts which may be observable under suitable conditions. To obtain 1 spurt in 10 seconds the radius of a spherical container would have to be about 9.7 cm., which is practical for pressures of 100 atmospheres.

A NEW METHOD FOR INVESTIGATING GAMMA RAYS.—W. Bothe and W. Kolhörster. (*Naturwissen.*, 7th December, 1928, summarised in *Nature*, 26th January, 1929, V. 123, p. 145.)

Secondary electrons set free by waves of very high frequency move off from their parent atoms approximately in the direction of the radiation; their direction (and therefore that of the radiation) can be found by setting a pair of Geiger electron-counters in various positions until they show a maximum number of coincident discharges, due to the individual electrons affecting each in turn. The method has an obvious application to the problem of the origin of the Cosmic rays, and the writers (in this preliminary account) mention that when relatively soft rays are excluded by a filter of 10 cm. of lead, the number of coincident discharges of the counters which cannot be ascribed to the presence of radioactive substances is increased threefold by rotation of the detecting system from the horizontal to the vertical. (See below.)

THE NATURE OF THE PENETRATING RADIATION.—W. Kolhörster and W. Bothe. (*Nature*, 27th April, 1929, V. 123, p. 638.)

Simultaneous film records of the effect on two "tube-counters" (Geiger and Muller: see April Abstracts, p. 220) indicate the probability that the radiation is of corpuscular nature and *not* of the gamma ray type.

PENETRATING RADIATIONS.—E. Rutherford. (*Nature*, 30th March, 1929, V. 123, p. 501.)

Summary of a lecture at the Royal Institution.

COSMIC RAYS. (*Nature*, 23rd March, 1929, V. 123, p. 472.)

Corlin finds a consistent variation in the intensity of the softer components during the sidereal day. If the soft rays are screened off, temporal fluctuations are not present; the obvious inference being that the more penetrating rays are produced ndifferently throughout space, but that at least a part of the softer radiation has a more localised origin. In a second communication it is suggested that the softer rays are really initially hard, but that they are produced inside material celestial bodies, and are softened by scattering on the way out. (*Cf.* Abstracts, 1928, V. 5, p. 230.)

THE ELECTRONIC CHARGE *e*.—J. H. J. Poole. (*Nature*, 6th April, 1929, V. 123, p. 530.)

Birge has pointed out the improbability that any of the measurements of the three physical quantities in the expression $hc/2\pi e^2$ could be so much in error as to account for the discrepancy between the experimental value of 137.2 and Eddington's recently published theoretical value of 136. The writer suggests, as a way out of the *impasse*, the "rather fantastic idea" that the intense electric field near the electron may have an

increasing effect on π. [But *Sci. News-Letter*, 16th February, 1929, announces that Siegbahn has just found an experimental value very near 136.]

COSMIC RAYS.—J. A. Gray. (*Nature*, 23rd March, 1929, V. 123, p. 447.)

Investigation of the results of Millikan and his colleagues leads the writer to disagree with their conclusions as to the rays falling into four bands, and with their deduction that atom building is taking place in outer space (see recent Abstracts).

DIFFRACTION OF CATHODE RAYS BY CALCITE.—S. Nishikawa and S. Kikuchi. (*Nature*, 10th November, 1928, V. 122, p. 726.)

A monochromatic beam of cathode rays was directed against a cleavage face of calcite at a grazing incidence, and the diffraction pattern was obtained on the photographic plate behind the crystal normal to the incident beam. The patterns consist of a number of bands of different widths and many black and white lines; sometimes also spots similar to Laue's. One conclusion drawn is that the structure-factor for X-ray reflection has a similar influence on cathode ray reflection.

LA POLARISATION DANS LA THÉORIE DES QUANTA DE LUMIÈRE (Polarisation in the Theory of Light Quanta).—J. Ullmo. (*Comptes Rendus*, 29th October, 1928, V. 187, pp. 758–761.)

The writer shows how the phenomena of polarisation can be explained as statistical effects due to the distribution and arrangement in space of the photons, without any hypotheses as to their internal structure such as are involved by other interpretations.

SUR LE CHAMP INTERNE DE POLARISATION (The Internal Field of Polarisation).—R. de Mallemann. (*Comptes Rendus*, 22nd October, 1928, V. 187, pp. 720–722).

An extension of the writer's paper referred to in Abstracts, 1928, p. 693.

RECENT THEORIES OF THE ATOM.—W. F. G. Swann. (*Journ. Opt. Soc. Am.*, September, 1928, V. 17, pp. 163–197.)

PROPRIÉTÉS DIÉLECTRIQUES ET STRUCTURE DES COLLOIDES HYDROPHILES (Dielectric Properties and Structure of the Hydrophil Colloids).—N. Marinesco. (*Comptes Rendus*, 2nd October, 1928, V. 187, pp. 718–720.)

When a liquid with permanent dipoles solidifies, its dielectric constant falls sharply owing to the forced orientation of the dipoles, which can no longer follow the reversals of the external field. The dissolving of an electrolyte in water produces the same effect; the ions condense and fix a large number of the dipoles, leading to a fall in the inductive capacity of the liquid. An identical blockage can be produced by absorption, as the writer explains in connection with colloids which swell up and retain a large quantity of water.

WAVE ATOMS.—P. R. Heyl. (*Scientific American*, November, 1928, pp. 406–408.)

A continuation of the article referred to in Abstracts, 1928, p. 470. 'The "inwardness of the new Schrödinger Atom concept" is explained, in the light of recent results connected with the reflection of rays and particles. Incidentally, the accident is described which led Davisson and Germer to their discovery of the regular reflection of electrons by a nickel crystal: the usual scattering by a nickel surface was being obtained when the glass bulb broke and the hot target was tarnished by the in-rushing air. To clean it, it was heated for some time in hydrogen. Regular reflection was then obtained, owing to the greatly increased size of crystals produced by the heating.

SCATTERING OF QUANTA WITH DIMINUTION OF FREQUENCY.—K. Darrow. (*Science*, 16th November, 1928, V. 68, pp. 488–490.)

The writer says that the correlation of several recent results in the scattering of quanta (Raman, Landsberg and Mandelstam, Compton, etc.), leads to the general principle that a quantum can divide its energy, giving up a part and retaining the remainder; and this can happen whenever there is an encounter between a quantum and an electron, atom or system of atoms capable of receiving energy in quantities smaller than the quantum originally possesses. He points out that this principle was adumbrated by Smekal in 1923, and that it was not appreciated probably because at that time it was difficult to conceive that a quantum could change its frequency and yet remain the same quantum. But now it is clear that electrons also possess the properties of wave-motion, and when an electron is speeded up or slowed down, its wavelength changes; "if we conceive that nevertheless it remains the same electron, can we do otherwise than suppose that a quantum retains its identity when its wavelength is altered?" See also long paper by same author (*Bell Tech. Journ.*, January, 1929, V. 8, pp. 64–93) in his series "Contemporary Advances in Physics."

ÜBER DIE AUSLÖSUNG VON SEKUNDÄRELEKTRONEN DURCH ELEKTRONEN VON 1–30 KILOVOLT (The Setting Free of Secondary Electrons by Electrons of 1–30 kV.).—E. Buchmann. (*Ann. der Physik.*, No. 20, V. 87, pp. 509–535.)

An extension of the work of Kossel, Compton and Voorhis at lower voltages.

ZUR POLARISATION DES KANALSTRAHLLICHTES IN SCHWACHEN ELEKTRISCHEN FELDERN (Polarisation of the Canal ray light in weak electric Fields).—E. Rupp. (*Ann. der Physik*, No. 19, V. 87, pp. 285–297.)

THÉORIE DE LA DIFFUSION DE LA LUMIÈRE PAR UN CORPS PLACÉ DANS UN CHAMP ÉLECTRIQUE OU MAGNÉTIQUE (Theory of the Diffusion of Light by a Body in an Electric or Magnetic Field).—Y. Rocard. (*Ann. de Physique*, November-December, 1928, V. 10, pp. 472–488.)

La Conductibilité Électrique (Electrical Conductivity).—W. J. de Haas. (*Journn. de Phys. et le Rad.*, September, 1928, V. 9, pp. 265–277.)

A description of the experiments made by the writer, with Sizoo and Voogd, on the supraconductors.

Neues zum Barkhauseneffect (New Information on the Barkhausen Effect).— –. Pfaffenberger. (Summary in *E.T.Z.*, 13th December, 1928, p. 1816.)

The swinging over of the elementary magnets owing to change of field was investigated after suitable amplification, using a string galvanometer. The quantitative distribution of the effect over the hysteresis curve was plotted ; there is a certain connection with the heat development. The length over which simultaneous induction change takes place has been measured and found to be about 3 m. [3 mm. ?] ; it is therefore independent of crystal length, and the Barkhausen effect cannot correspond to magnetostriction effects.

Thermoelectric Power of Selenium Crystals. —R. M. Holmes and A. B. Rooney. (*Phys. Review*, June, 1928, V. 31, p. 1126.)

Selenium crystals were prepared by slow condensation of the vapour in a tube evacuated to 0.008 mm., one end of the tube being in the open air, the other in an oven with automatic temperature control. The best crystals were formed on a thread of pyrex glass in the middle of the tube. The thermoelectric force (against copper) follows the equation $E = 1.10\ t + 0.00017\ t^2 m\ V.$ between 0 and 180 deg. C., and is the greatest value hitherto measured, being 800 times as large as that for copper-lead. If the one contact is at 0 deg. C., the thermoelectric force is approximately a linear function of t, showing that the Peltier effect is responsible for almost the whole of it. In certain crystals there is an E.M.F. from light absorption, which may amount to 10 mv. for a 100 w. lamp at 50 cm. distance.

MISCELLANEOUS.

Hot Cathode Neon Arcs.—C. G. Found and J. D. Forney. (*Journ. Am.I.E.E.*, December, 1928, V. 47, pp. 855–859.)

"In general, we believe that the hot cathode neon arc is the most efficient high-intensity source of red light." The substitution of a hot cathode reduces the cathode drop to a few volts and all the difficulties caused by the high cathode fall are avoided. At a pressure of 2 mm. practically all of the tube is filled with positive column and a current of about 3.5 amps. is produced when the heater is taking 60 watts. The tubes are started (1) by bringing an H.F. discharge close to the cathode ; (2) by an auxiliary starting anode ; or (3) by an inductance " kick."

Various types are discussed together with their uses and advantages : important features being their long life and their independence of surrounding temperature.

Ultra-violet Light and Tracing Cloth. (*Science*, 15th March, 1929, V. 69, p. xiv.)

Ordinary tracing cloth has been found to pass the ultra-violet part of sunlight very well, though a single thickness cuts off much of the heat and glare.

Some Photoelectric and Glow-Discharge Devices and Their Applications to Industry.—J. V. Breisky and E. O. Erickson. (*Journ. Am.I.E.E.*, February, 1929, V. 48, pp. 118–121.)

Sorting and counting ; matching colours ; smoke recording (for smoke stacks) ; smoke detection (alarms, automatic CO_2 equipment, etc.) ; grid-glow tube Oil-Burner control (instantaneous, whereas thermostatic controls are too slow to prevent certain troubles). *Cf. Engineer*, 22nd March, 1929, p. 323, where an article in *Nature* is referred to on the application of photoelectric and selenium cells to operate alarms and automatic controls regulating the level of liquids in tanks and stand pipes : the device being particularly useful when the liquids are under high pressures so that the standard methods of level control cannot be used.

The Excitation of Luminescence by the Agitation of Mercury in Glass and Transparent Fused Silica Tubes and Vessels.—W. L. Lemcke. (*Science*, 18th January, 1929, V. 69, pp. 75–78.)

Use of the Oscillograph for Measuring Non-Electrical Quantities.—D. F. Miner and W. B. Batten. (*Journ. Am.I.E.E.*, February, 1929, V. 48, pp. 126–129.)

Speed recording ; turbine blade vibration, etc.; timing a sequence of operations ; stresses—railroad track and locomotive side rods ; pressure recording.

Radium as a Means of Preventing Sparks from Static Electricity in certain Factories. (*Nature*, 13th April, 1929, V. 123, pp. 578–579.)

In a Russian rubber factory a capsule of radium is used to ionise the air so that the electric charges (produced by friction of rubber-covered fabric with parts of the drying machinery) flow through it harmlessly to earth.

A Recording Photoelectric Colour Analyser. —A. C. Hardy. (*Journ. Opt. Soc. Am.*, February, 1929, V. 18, pp. 96–117.)

A very full treatment of an apparatus similar to or identical with that referred to in May Abstracts. The choice of the type of photoelectric cell for the purpose in question, various ways of connecting the cell to the first stage of amplification, the design of the amplifier, etc., are dealt with.

Selenium Cell Developments. (*Elec. Review*, 23rd November, 1928, V. 103, pp. 910–911.)

The automatic lighting of street lamps, automatic sectional signalling and train control are dealt with.

SOUND BEAM SENDING HORN. (*Scient. Amer.*, January, 1929, p. 89.)

"The practicability of directing a beam of sound to a definite distant point was demonstrated recently when officers of the U.S. Navy Dirigible, flying at 1,500 feet, distinctly heard the voices of officials of the Victor Talking Machine Company, as well as a programme of music and constant tone signals, projected to them by the recently developed super-directional horn mounted on the roof of a ten-story building."

EIN ELEKTROMECHANISCHER SCHWINGUNGSERZEUGER (SCHWINGUNGSMOTOR) (An Electromechanical Oscillation Generator—Oscillating Motor).—W. Späth. (*E.T.Z.*, 28th March, 1929, pp. 455–458.)

The chief use of this new motor seems to lie in the testing of materials.

AIRCRAFT COMPASS PROBLEMS.—T. R. Rhea. (*Gen. Elec. Review*, April, 1929, V. 32, pp. 190–193.)

Certain disadvantages of the ordinary earth inductor compass are pointed out; these are absent in the "Magneto Compass" recently developed by Tear, in which the earth's flux is concentrated in a specially shaped bar of high permeability and low coercive force; the bar has a gap at its mid-point in which a very small wound armature spins rapidly on a vertical axis which carries a small commutator.

ELECTRICAL AIDS TO NAVIGATION.—R. H. Marriott. (*Journ. Am.I.E.E.*, March, 1929, V. 48, pp. 195–199.)

Short descriptions of the Earth-Inductor Compass, Radio Compass, Radio Beacon, Submarine Signal (80 miles range has been obtained), Combined Submarine Sound Beacon and Radio Beacon (for obtaining distance: Abstracts, 1928, p. 649; 1929, p. 107; both J. H. Service), Sonic Depth Finding, and Leader Gear (proposed also for aircraft, and installed in France on a pole line). Proposals are mentioned:—for fog penetration, high-power Geissler-type tubes working in conjunction with photoelectric cells which are more sensitive than the eye to this kind of light; aircraft height above ground to be determined by sound reflection, radio reflection (Alexanderson—May Abstracts, p. 286); variation of air dielectric of a condenser to be used as a substitute for a barometer.

ÜBER DIE BIOLOGISCHE WIRKUNG KURZER ELEKTRISCHER WELLEN (The Biological Effects of Short Electric Waves).—E. Schliephake. (*E.T.Z.*, 18th April, 1929, p. 574.)

A short outline of the results obtained by the writer, by Esau's methods, on waves from 5 m. down. The most obvious results are heating effects, which can be obtained far deeper than by ordinary diathermy. For this work, the field between the plates of a condenser is used; but there are also effects in the ordinary radiation field—a production of nervous irritability, and slight raising of body temperature—the former being probably due to a purely electrical action independent of heating; it was more marked with the 3 m. wave than with the 5 m. The research is continuing.

THE MEASUREMENT OF EMOTIONS.—G. G. Blake. (*Elec. Review*, 23rd November, 1928, V. 103, pp. 882–884.)

The increase in conductance of the human body under the stimulus of emotion is measured by a thermionic valve method and compared with the reaction produced by an electric shock at a known voltage. The increase of conductance appears a second or two after the cause. Thoughts passing through the subject's mind may approximate to a 12-volt shock. An interesting point is that any subject is more sensitive to a self-inflicted shock than to one externally and unexpectedly applied. The application of the method to the investigation of nervous fatigue and the effects of drugs is suggested.

REGELWIDRIGKEITEN IN DER WIRKUNGSWEISE EINIGER KONTAKTDETEKTOREN (Anomalous Behaviour of Certain Contact Detectors).—R. H. Elsner. (*Rad. f. Alle*, March, 1929, pp. 107–109.)

An article on Grosskowski's work on detectors with abnormal dynamic characteristics (Abstracts, 1928, V. 5, p. 225). The writer points out that if such detectors are used as indicators in wavemeters, bridges, etc., they may lead to serious errors. He also suggests that use might be made of the unusual characteristic in atmospheric elimination.

VERY HIGH VACUUM CONTACT-BREAKER.—(*French Patent* 621316549, Siemens-Schuckert, published 10th December, 1928.)

The contact-breaker is contained in a glass vessel. Electrodes (tantalum or tungsten) are oil- or water-cooled, and the glass vessel contains (*a*) a filament which can be heated so as to provide an electronic bombardment to out-gas the electrodes; (*b*) a fixed electrode coated with magnesium or other "getter"—this also can be heated by electron bombardment; and (*c*) a three-electrode valve system which "controls" the vacuum.

SUR LE SONDAGE MAGNÉTIQUE DES ARBRES DE MACHINES (Magnetic Sounding of Machine Shafts).—J. Peltier. (*Comptes Rendus*, 4th March, 1929, V. 188, pp. 701–703.)

Flaws, etc., in a rotating axle can be detected by their effect on a polarised electromagnet system such as that of a telephone ear-piece. Vibration (of turbine shafts, for example) could be studied with the help of a similar arrangement.

THE "DEION" CIRCUIT BREAKER. (*Elec. Review*, 29th March, 1929, V. 104, p. 590.)

A note on Slepian's new circuit breaker, in which the arc is driven by a magnetic field over a circular metallic path at the rate of 2,400 miles per hour; the metal, instead of yielding ions to the arc, removes them from it, so that after 30 or 40 circuits of the path the arc is extinguished.

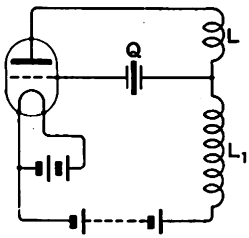
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

PIEZO-CONTROLLED GENERATORS.

(*Convention date* (*Germany*), *26th October*, 1926. *No.* 279845.)

The figure shows a simplified circuit connection for generating oscillations of stabilised frequency. The plate and cathode of a thermionic valve are directly connected through an inductance coil L, L_1. The piezo crystal Q is connected directly between the grid and an intermediate tapping on the coil. The tapping point is so chosen that the inductance L has approximately the same natural frequency as that of the crystal, whilst the inductance L_1 is comparatively high and acts as a choke.



No. 279845.

Patent issued to Radio Frequenz G.M.B.H. and H. Eberhard.

THERMIONIC OSCILLATION GENERATORS.

(*Application date*, *20th October*, 1927. *No.* 304369.)

In order to generate high-frequency oscillations of constant amplitude, free from harmonics, a negative-resistance device such as a screened-grid valve or pentode, operating on the falling portion of its characteristic curve, is associated with a resonant output circuit, and with means for tapping off a constant voltage from that circuit. Preferably the resonant output circuit is shunted by a condenser and resistance in series, the required voltage being tapped off from the series resistance to a subsequent amplifier.

Patent issued to W. S. Smith and N. W. McLachlan.

MODULATING SYSTEMS.

(*Convention date* (*Germany*), *14th October*, 1927. *No.* 298647.)

In picture-transmission and high-speed telegraphy it is usual to introduce an intermediate-frequency carrier, which is first modulated by the picture or other signal currents, and is then eliminated prior to the actual modulation of the transmitted wave, so as not to widen unduly the radiated side-bands.

According to this invention the modulated intermediate-frequency carrier is applied directly to the grid of the high-frequency modulator, and the anode of the latter is coupled to the final transmitter valve through a wave-trap circuit designed to absorb the unwanted carrier frequency.

Patent issued to Telefunken, G.M.B.H.

DETECTOR CIRCUITS.

(*Application date*, *5th December*, 1927. *No.* 304430.)

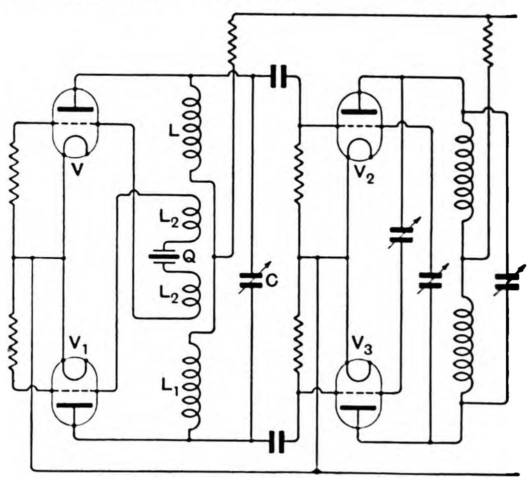
In order to separate the radio-frequency from the audio-frequency currents, either in the output circuit of a crystal or valve detector, or on the input side of a leaky-grid rectifier, a low-pass filter circuit is employed comprising a number of series chokes and shunt condensers. The filter is so designed that regarded from its input side (which receives mixed radio and audio frequencies) it offers a low impedance to radio-frequency currents, while regarded from its output side (which feeds an audio-frequency telephone or loud speaker) it has a high impedance for audio frequency currents. It is also designed to have a high attenuation factor for the lowest radio frequencies and a low attenuation factor for the highest audio frequencies.

Patent issued to Graham Amplion, Ltd., and P. K. Turner.

STABILISED PUSH-PULL OSCILLATORS.

(*Application date*, *24th October*, 1927. *No.* 304382.)

Two back-coupled valves, V, V_1, acting alternately upon the tuned oscillatory circuit, L, L_1, C are controlled by a single piezo crystal Q. The crystal is arranged symmetrically with respect to the two grids of the double-acting oscillator, and is associated with coils L_2, also arranged symmetrically and coupled to the main oscillatory circuit. Subsequent stages of push-pull amplification are coupled to the generator, as shown at V_2, V_3.



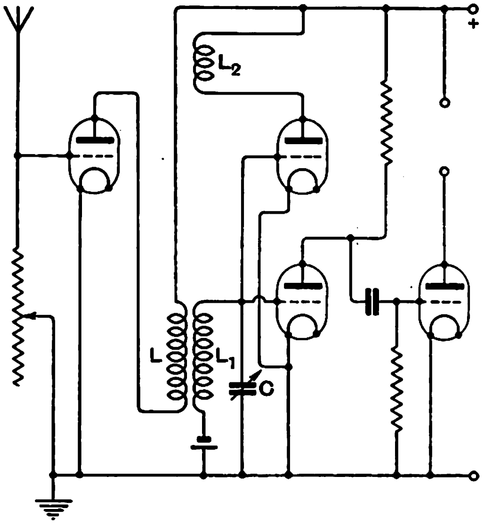
No. 304382.

Patent issued to J. K. im Thurn, G. Shearing, and C. Matthews.

REDUCING STATIC INTERFERENCE.

(*Application date*, 9*th November*, 1927. *No.* 303608.)

The input to the H.F. valve is taken from a non-inductive resistance in the aperiodic aerial. The non-selective system is then compensated by feeding the output from the H.F. valve to two valves in parallel, the first acting as a detector, and



No. 303608.

the second as a local generator of oscillations of the desired signal frequency. This frequency is determined by the setting of the condenser *C* in combination with the inductance L_1. The coupling of the coils L_1, L_2 determines the strength of the local oscillation, and is stated to produce a highly-selective combination largely impervious to static disturbance.

Patent issued to The Edison Swan Electric Co., Ltd., and L. H. Soundy.

LOUD SPEAKERS.

(*Application date*, 31*st January*, 1928. *No.* 304487.)

In order to utilise the power of the magnet to the fullest degree, and also to provide a more uniform distribution of sound, several armatures are arranged symmetrically around the air-gap, each co-operating with a separate diaphragm. Preferably three such armatures are arranged near pole-pieces of triangular cross-section, the three respective diaphragms forming, in section, the sides of an equilateral triangle.

Patent issued to C. French.

SCANNING FOR TELEVISION, ETC.

(*Application date*, 5*th July*, 1927. *No.* 303771.)

A system for transmitting still-life pictures or moving scenes is characterised by the fact that the bands or zones into which the picture is analysed in transmission, and from which it is synthesised in reception, are made narrower over the central parts of the picture than at the edges. The object is to take advantage of the known characteristic of the human eye, which sees an extended object with acute definition at the centre, and then shades off to areas of more or less indistinct vision.

Patent issued to J. L. Baird and Television, Ltd.

RECEIVING SETS.

(*Application date*, 15*th October*, 1927. *No.* 303587.)

The set as a whole is designed so that it can readily be used either with an A.C. mains-eliminator, or with batteries, as desired. The *HT*, *LT*, and grid-biasing contacts are brought out into line at the side of the cabinet, and are connected in groups by three straps where the current supply is taken from batteries. When the supply is to be taken from the mains, the straps are removed, and a rectifier unit provided with a corresponding line of terminal contacts is fitted snugly against the cabinet.

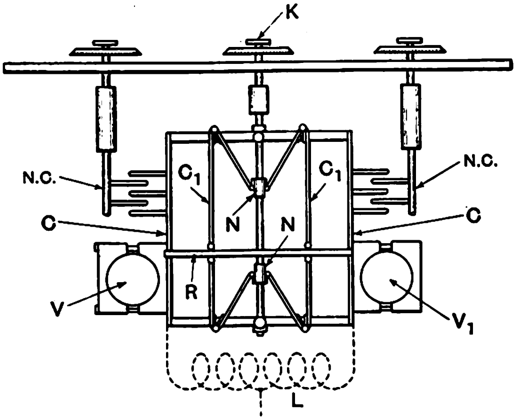
Patent issued to S. G. S. Dicker.

SHORT-WAVE TRANSMITTERS.

(*Convention date* (*U.S.A.*), 19*th March*, 1927. *No.* 287462.)

In order to minimise the length of leads between the circuit components of a high-powered short-wave transmitter, the tuning-condenser is robustly constructed and serves directly to support the valves and other parts. The condenser consists of two fixed plates *C* and two movable plates C_1. The resultant capacities are in series and their effective value is adjusted by moving the plates C_1 to and fro along an insulated guide-rail *R*. For this purpose a hand-control *K* moves the two nuts *N* in opposite directions along a screwed spindle.

The fixed outer plates *C* are made to support the transmitting valves *V*, V_1 arranged in push-pull,



No. 287462.

the heavy gauge circuit inductance *L*, and the fixed plates of the neutralising condensers *NC*. The control knobs of the latter are taken through the same panel as the tuning-control *K*.

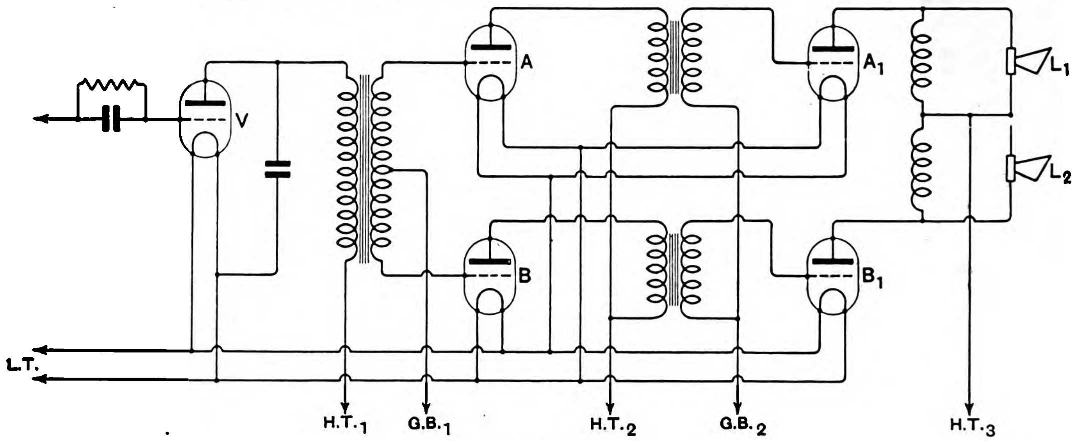
Patent issued to Marconi's Wireless Telegraph Co., Ltd.

L.F. AMPLIFIERS.

(*Application date*, 20*th February*, 1928. *No.* 303681.)

Two loud speakers L_1, L_2 are fed through separate amplifying-channels from a common input. By suitable design each amplifying channel can be given any desired frequency characteristic, so that, for instance, one speaker favours the higher, and the second the lower notes. The input valve V is fed from an aerial or gramophone pick-up, the output being passed in push-pull relation to the Channels A, A_1, L_1 and B, B_1, L_2 respectively. The arrangement is such that a common source of high and low tension and grid-biasing voltage can be used for all the valves.

Patent issued to L. F. Douglass.



No. 303681.

LOUD SPEAKER HORNS.

(*Application date*, 15*th March*, 1928. *No.* 304511.)

A sound horn of the cabinet type is formed with an inlet passage of gradually-increasing area, passing to a central conduit. The latter is also of gradually-increasing area and leads to two outlets arranged at opposite sides of the cabinet. Each outlet is of large area and has a depth approximately equal to the length of the inlet passage. The dimensions of the horn as a whole follow a logarithmic or exponential law.

Patent issued to Electrical Improvements, Ltd., and L. C. Grant.

RECTIFIERS.

(*Convention date* (*Germany*), 6*th October*, 1926. *No.* 278731.)

Copper pyrites and zincite crystals are arranged in layers between metal discs in such a way that they make good contact with the metal backing and with each other. The combination gives a heavy-current rectifier which can be used for supplying *HT* and *LT* to a valve receiver.

Patent issued to M. Singelmann.

INDIRECTLY HEATED VALVES.

(*Application date*, 26*th August*, 1927. *No.* 303037.)

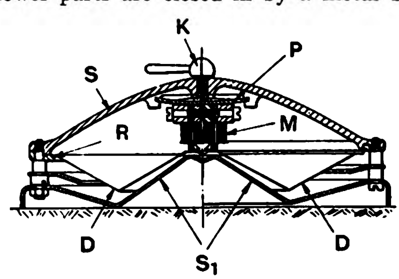
When the filament of an indirectly-heated valve is energised from a source of alternating voltage, electrostatic action between the heater and the filament proper is liable to give rise to undesirable interference. To prevent this a metallic shield or screen, perforated to allow the free passage of heat, is interposed between the heater and the cathode, and is either earthed or connected to a point of fixed potential.

Patent issued to W. S. Smith and N. W. McLachlan.

LOUD SPEAKERS.

(*Convention date* (*Austria*), 11*th January*, 1927. *No.* 283492.)

The diaphragm consists of two conical surfaces *D* clamped around the edges between the sound box or casing *S* and an annular ring *R*. At the top of the casing a square plate *P* is secured between undercut lugs, as shown, and carries the magnets. A control screw *K* flexes the plate *P* and so adjusts the gap between the pole-pieces and the diaphragm. The lower parts are closed in by a metal bottom plate S_1 which also serves as a stand. The resultant shape of the air-passage is such that the volume of fluid set in motion increases progressively from the centre outwards.



No. 283492.

Patent issued to E. D. Feldman.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. JULY, 1929. No. 70.

Editorial.

The Effect of the Earth on Short-wave Radiation from Vertical and Horizontal Aerials.

IT is nearly twenty years since Sommerfeld published his paper on the radiation from a vertical aerial, and during the interval a number of mathematical physicists have worked at the problem. Sommerfeld took into consideration the nature of the ground, but assumed the earth to be plane; at that date little was known of the action of the Kennelly-Heaviside layer, and it was generally assumed that the only part of the radiation from the antenna, which was of practical importance, was that propagated along the surface of the earth. Sommerfeld, therefore, confined himself to radiation in this direction and his results are not applicable to radiation at a considerable angle to the earth's surface, which radiation we now know may be of greater importance than that propagated horizontally. Although recent experiments have shown that for long distance short-wave transmission the best results are obtained by directing the beam in the horizontal direction, it is not because the waves travel around the earth along the surface, but because the beam which is radiated tangentially appears to suffer less attenuation in its trajectory in the upper atmosphere between the two stations. In the simple assumption of long waves travelling over a plane earth of infinite conductivity, the problem was closely analogous to the transmission of alternating currents along a transmission line of zero resistance, and one could imagine the electric field to be confined between a lower infinite plane and an upper cone. As soon as the earth resistance is taken into account this simple analogy must be given up. The waves are no longer spherical and merely retarded and attenuated by the earth's resistance. Sommerfeld showed that the effect of the resistance was to split up the waves into two parts, the lower part attached to the earth and propagated, as a cylindrical surface wave, the upper part, freed from the guidance of the earth and propagated as a spherical wave into space. The splitting up is a continual process, some of the energy of the surface wave being continually lost by radiation into space. Considerable light was thrown on the nature of these processes by the diagrams which were published by Epstein in 1911, showing the lines of force for different conditions as calculated from Sommerfeld's results.

A 2

In all these researches the radiation was assumed to leave the aerial as if the latter were a vertical dipole of a height which could be neglected in comparison with the wavelength. With the recent development of short wave transmission and with our knowledge of the important *rôle* played by the upper atmosphere, the assumptions made in many of these earlier researches are no longer tenable. We are concerned now with the radiation from aerials which are not only of a height comparable with the wavelength, but which are situated at a distance above the ground which is also comparable with the wavelength; we are also concerned with the distribution of the radiation, that is to say, how the radiated energy varies with the angle of inclination. It is no longer permissible to assume that the aerial is vertical since horizontal aerials are now largely employed and are of special interest from a theoretical point of view.

One of the most important contributions on this subject was that of T. L. Eckersley in his paper before the Institution of Electrical Engineers in 1927. A paper has just been published by M. J. O. Strutt in the *Annalen der Physik* (page 721, 1929), in which the subject is treated in a somewhat different manner, and it is satisfactory to note that the formula derived for a vertical dipole is identical with that obtained by Eckersley. A large number of numerical examples are calculated and curves plotted showing the distribution of radiation for different values of the dielectric constant and conductivity of the earth, the assumed wavelength being always 30 m. It is interesting to note that the dielectric constant appears to be the more important characteristic, and that conductivities of such a value that the conduction currents are equal to the displacement currents do not appreciably modify the results obtained for an ideal dielectric earth with no conduction currents. As one would expect, an increase in the dielectric constant of the earth increases the energy radiated in the upper hemisphere for the same aerial current; especially is this noticeable in directions near the horizontal. As one raises a vertical dipole above the earth the horizontally radiated energy increases, but the high-angle radiation may increase or decrease. The maximum radiation occurs at an angle between 20 and 40 degrees to the horizontal; although that in the horizontal direction is zero, it is quite considerable a few degrees above the horizontal. The radiation is much less than would be obtained with a perfectly conducting earth, since, even if the earth were a perfect dielectric, *i.e.*, free from losses, a certain fraction of the energy would be radiated into the lower hemisphere and thus lost.

The horizontal dipole leads to some striking results; if it is near the earth the radiation is nearly symmetrical about a vertical axis and does not exhibit the pronounced directive effect which one might expect. The total useful energy radiated from a horizontal dipole always increases with its height whatever the nature of the earth, whereas with a vertical dipole it may increase or decrease, depending on the nature of the earth. Perhaps the most important result of the investigation is that the usefully radiated energy of a horizontal antenna, if placed at a proper height, is not less than that from a similar vertical antenna, which agrees with the results of long distance measurements with both types of aerials.

G. W. O. H.

Moving Coil Loud Speakers.

With Particular Reference to the Free-Edge Cone Type.

By C. R. Cosens, M.A.

Object of Discussion.

THE general outlines of the design of a moving coil loud speaker are well known; we require a *diaphragm* or "cone," suitably suspended, attached to a *coil*, which moves in a *magnetic field*. But as soon as we try to get down to dimensions and numerical values for these three, diaphragm, coil, and field, it is found that ideas are, at best, somewhat vague.

Now although loud speakers in general are not suitable for simple mathematical treatment, it so happens that the "moving-coil free-edge cone" is amenable to analysis if we make certain simplifying assumptions; and the results so obtained appear to resemble the results of experiment sufficiently closely to be of value for design purposes. As it is generally agreed that this type of loud speaker can be made to give the most realistic reproduction of any which is at present available, it appears worth while to give the method of dealing with the problem in *E.W. & W.E.*, together with graphs and tables of results for some particular cases.

For perfect reproduction we may say vaguely that we want the relative volumes of different parts of the musical scale to be correct, but to treat the subject mathematically we require a definition of "volume."

Lord Rayleigh ("Theory of Sound," Vol. II, para. 245) defines "*intensity*" of sound at a point as follows:—

"*The rate at which energy is transmitted across unit area of a plane parallel to the front of a progressive wave may be regarded as the mechanical measure of the intensity.*"

If the "intensity" as above defined be integrated over a closed surface containing a source of sound, we may call the result the "*Output*"; this is clearly the mean rate at which the source of sound does work upon the air, and we shall denote it by W. This gives a numerical value to what is usually called volume.

As we want a numerical measure of how far our reproduction falls short of perfection, we must first consider how "perfect" reproduction should be defined. It is clear that what we need is that the *output* of sound given by the loud speaker shall be proportional to the intensity in the studio at the transmitting station, independent of frequency. We therefore have to consider the whole chain of apparatus from the microphone to the loud speaker, and it is desirable to know the frequency characteristics of each part of the chain. In default of other information, we must make some assumption as to the frequency characteristic of the pieces of apparatus in the chain other than the loud speaker itself (with which it is essential to consider the power stage of the receiver, since the loud speaker is the load in the anode circuit of the latter). It is found convenient to work in terms of $\mathcal{E}_g$, the R.M.S. value of the E.M.F. applied to the grid of the receiver power stage, and to assume some relation between $\mathcal{E}_g$ and the intensity of sound in the transmitting studio. The most simple assumption is that the E.M.F. $\mathcal{E}_g$ applied to the grid of the power stage of the receiver is proportional to the E.M.F. generated by the microphone system in the transmitting studio at any frequency.

We must also assume that when a sound of given intensity is produced in the studio, the energy absorbed from the air by the microphone and converted into electrical energy will be proportional to the original intensity of the sound, irrespective of frequency. (If this is not true for the microphone alone, an attenuation network will be used to correct it, and the whole combination of microphone and network will form the "microphone system.")

Now if the microphone system feeds into a fixed resistance, such as the windings of a potentiometer used for volume control, the electrical energy generated will be proportional to the *square* of the generated E.M.F.; to which the receiver E.M.F. $\mathcal{E}_g$ has in turn been assumed proportional.

Hence $\mathcal{E}_g^2$ will be proportional to the sound intensity in the transmitting studio, and if we want perfectly faithful reproduction we must have our loud speaker output proportional to this, *i.e.*

$$W \propto \mathcal{E}_g^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

irrespective of frequency.

Types of Distortion.

If at any one frequency W is not proportional to $\mathcal{E}_g^2$ we shall have *amplitude distortion.* We shall show that this only occurs as a second order effect, if at all.

If the ratio of W to $\mathcal{E}_g^2$ is not the same at all frequencies we shall have *frequency distortion.* We shall show that this does occur, and consider how its effects may be minimised.

If we have two different frequencies to be dealt with at the same time, in the absence of the above forms of distortion their relative *amplitudes* would be preserved; although their relative *phases* might be altered, giving *phase distortion.* This inevitably occurs wherever there is iron present, and in any land-line, as well as in any loud speaker. As regards the reproduction of music and speech this form of distortion is of no consequence; the Helmholtz theory of hearing assumes that the ear performs a harmonic analysis of a complex sound by means of resonators, and is sensitive to the relative *amplitudes* of the component pure tones, but not to their relative *phase.*

Assumed Shape and Rigidity of Diaphragm.

The only real difficulty met with in the analysis is that of estimating the reaction of the air on the moving diaphragm or "cone"; fortunately a result obtained by Lord Rayleigh many years ago appears applicable, at least as a first approximation to the actual facts.

In "Theory of Sound," Vol. II, § 302, there is given a discussion of the reaction of the air on a perfectly rigid plane circular disc, moving harmonically in a perfectly fitting aperture in an infinite plane baffle, the disc and baffle forming the boundary of a semi-infinite mass of gas (in our case, air).

As a first approximation to the effect of the air on an actual loud speaker diaphragm, we may take *double* the values given by Rayleigh (since we have air on *both* sides of the diaphragm, whereas Rayleigh's disc had air on *one* side only).

The form of loud speaker which we are to analyse is then provided with a perfectly plane circular diaphragm, which is absolutely rigid. An actual practical diaphragm is of conical form, and the air pressures on the front (concave) side will be greater than those for the plane disc, but this is partly compensated for by the pressures on the back (convex) side of the cone being less than for the plane disc. In any case the effect of the proximity of the magnet system will be to introduce errors at least as great as those due to the actual diaphragm being conical instead of plane, and it would appear impossible to allow for the effect of the magnet. The human ear is fortunately insensitive to differences of sound intensity less than 3 or 4 to 1 (or else loud speaker reproduction would be even less satisfactory than it is), and therefore our results will be of some value, even if there are actually considerable errors. It is probable that the difference between calculation and practice would not exceed, say, 25 per cent., and the *relative* errors as between different frequencies would be less than this.

Again, it is obvious that no actual diaphragm is perfectly rigid, but it would appear that the difficulties of analysis of a non-rigid diaphragm would be enormous. The effects of want of rigidity would be felt most in the reproduction of the higher frequencies, where the diaphragm would have two types of motion, a simple movement as a whole, and an internal vibration of the type met with in fixed-edge reed-driven cones. The effects in practice appear to be an accentuation of the higher frequencies (which is very desirable, as will be seen; but for this effect we should have little or nothing above about 1,500 cycles); at the lower frequencies the effects will be negligible.

Finally, we cannot have an infinite baffle, but the error due to assuming our baffle infinite will be small except at the lowest frequencies.

Approximate Analysis of Moving Coil Free-edge Loud Speaker.

(We assume all quantities measured on the absolute C.G.S. electromagnetic system.)

Consider a cylindrical moving coil of radius c, free to move axially in a uniform radial magnetic field, rigidly fixed to a circular diaphragm of radius C, coaxial with the coil, which moves in an aperture in a plane "baffle."

Let: γ = Total length of wire in moving coil.

B = Flux-density in air-gap.

x = axial displacement of coil at any instant.

$v = \dfrac{dx}{dt}$ = (instantaneous) velocity of coil.

F = driving force on coil, tending to increase x, due to current in coil.

i = Current in coil at any instant.

write also $\Psi = \gamma B$.

Due to the current i in the coil, the mechanical force F produced will be

$$F = \Psi i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Due to the motion of the coil in the magnetic field, a back E.M.F. will be generated, given by:

$$e_b = \Psi v \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Mechanical Constants.

Let the ends of the coil be supposed disconnected and the ends insulated, and let the coil and diaphragm be made to vibrate by an axial force of instantaneous value F dynes, with a frequency $f = \dfrac{\omega}{2\pi}$ oscillations per second. The equation of the resultant motion will be of the form:

$$m\frac{d^2x}{dt^2} + \beta\frac{dx}{dt} + hx = F \quad \ldots \quad \ldots \quad (4)$$

where m = the "Effective mass" of the coil, diaphragm, etc., including that of a mass of air moving with the diaphragm (the "adherent air"), and β is a "damping coefficient," while h is the restoring force for unit displacement due to the suspension (usually made negligible). As shown in Lord Rayleigh's "Theory of Sound," m and β vary with frequency.

Electrical Constants of Coil.

Let r_c and l_c be the effective A.C. resistance and inductance of the coil supposed *immovably fixed* in the air-gap of the field-magnet (*e.g.*, as measured on a Heaviside-Campbell bridge).

Connections of Coil and Associated Apparatus.

Let the moving coil be connected to the secondary of an output transformer of step-down ratio ρ : 1, the primary of which is in the anode circuit of a valve as shown in Figure 1. Let μ and R_a be the amplification factor and slope-resistance ("impedance") of the valve. Let r_p, r_s, l_p, l_s be the primary and secondary resistances and leakage inductances of the transformer.

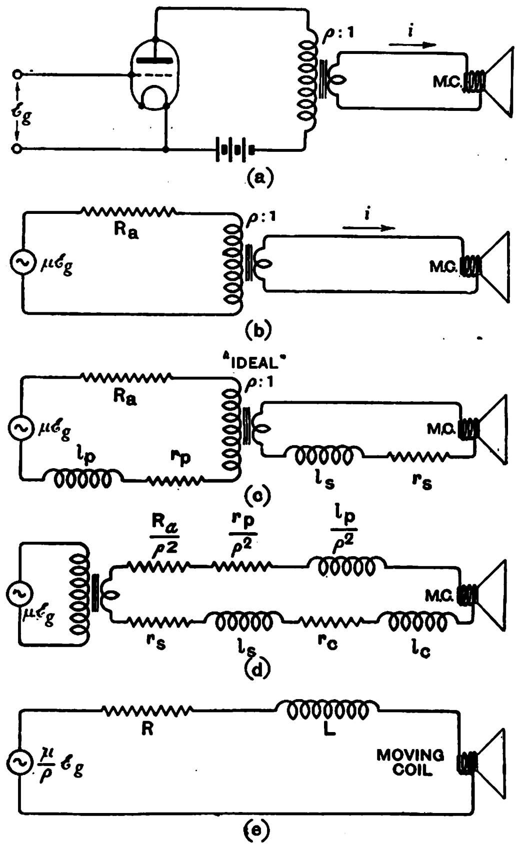

Fig. 1.

If a harmonic E.M.F. $e_g = E_g \sin \omega t$ applied to the grid of the valve cause a

current i to flow in the moving coil, we can replace the valve by an ordinary resistance R_a, and an E.M.F. μe_g acting in series with it, as in Figure 1(b).

We now replace the actual transformer by an "ideal" transformer having the imperfections (r_p, r_s, l_p, l_s) outside the transformer itself; and finally we transfer everything to the secondary of the transformer, and if we imagine the imperfections r_c and l_c of the coil also taken outside, we can replace the whole by the arrangement of Figure 1(e), where:

$$\left.\begin{aligned} R &= \left(r_c + r_s + \frac{1}{\rho^2}r_p + \frac{1}{\rho^2}R_a\right) \\ L &= \left(l_c + l_s + \frac{1}{\rho^2}l_p\right) \end{aligned}\right\} \quad \ldots \quad (5)$$

and where the moving coil is now supposed to have no resistance or inductance (but still to generate the E.M.F. given by (3) due to motion in the magnetic field).

Then:

$$L\frac{di}{dt} + Ri + \Psi v = \frac{\mu}{\rho}E_g \sin \omega t \quad \ldots \quad (6)$$

Combining (2) and (4), we have:

$$m\frac{d^2x}{dt^2} + \beta\frac{dx}{dt} + hx = \Psi i \quad \ldots \quad (7)$$

It will be found convenient to solve (6) and (7) for $v = dx/dt$ in terms of

$$e_g = E_g \sin \omega t.$$

Using the Heaviside operator notation ($D \equiv d/dt$), (6) and (7) become:

$$(LD + R)i + \Psi v = \frac{\mu}{\rho}E_g \sin \omega t \quad \ldots \quad (6a)$$

$$\left(mD + \beta + \frac{h}{D}\right)v = \Psi i \quad \ldots \quad (7a)$$

since ($v \equiv dx/dt \equiv D\,.\,x$, and therefore

$$x = \frac{1}{D}\,.\,v).$$

Eliminating i between (6a) and (7a), we have:

$$(LD + R)\left(mD + \beta + \frac{h}{D}\right)v + \Psi^2 v = \frac{\mu}{\rho}\Psi E_g \sin \omega t \quad \ldots \quad (8)$$

We may leave the complementary function of (8) out of consideration for the present, since it will represent a "transient" term rapidly damped out, and confine our attention to finding a Particular Integral. Before proceeding in the usual manner, note that h/D is to operate on v, which will clearly be a simple harmonic function of period $\omega/2\pi$; hence we may write

$$\frac{h}{D} = \frac{hD}{D^2} = -\frac{h}{\omega^2}\,.\,D$$

for the purposes of finding the particular integral we require.

Hence (8) becomes:

$$[LD + R]\left[\left(m - \frac{h}{\omega^2}\right)D + \beta\right]v + \Psi^2 v = \frac{\mu}{\rho}\Psi E_g \sin \omega t \quad \ldots \quad (8a)$$

If, for brevity, we now write:

$$\tau = \frac{1}{\beta}\left(m - \frac{h}{\omega^2}\right);\ Q = \frac{\Psi^2}{\beta} \quad \ldots \quad (9)$$

(a consideration of dimensions shows that τ is a period of time, *i.e.*, seconds, while Q is of the dimensions of an absolute C.G.S. unit of resistance) we have:

$$(LD + R)(\tau D + 1)v + Qv = \frac{\mu}{\rho}\frac{\Psi}{\beta}E_g \sin \omega t \quad \ldots \quad (10)$$

whence

$$\begin{aligned} v &= \frac{\mu\Psi}{\rho\beta}E_g\frac{1}{\tau LD^2 + (L + \tau R)D + (R + Q)}\sin \omega t \\ &= \frac{\mu\Psi}{\rho\beta}E_g\frac{(R+Q-\omega^2\tau L)-(L+\tau R)D}{(R+Q-\omega^2\tau L)^2-(L+\tau R)^2D^2}\sin \omega t \\ &= \frac{\mu\Psi}{\rho\beta}E_g\frac{(R+Q-\omega^2\tau L)\sin \omega t-(L+\tau R)\omega\cos \omega t}{(R+Q-\omega^2\tau L)^2+\omega^2(L+\tau R)^2} \\ &= \frac{\mu\Psi}{\rho\beta}\frac{E_g \sin(\omega t - \lambda)}{\sqrt{(R + Q + \omega^2\tau L)^2 + \omega^2(L + \tau R)^2}} \quad \ldots \quad \ldots \quad (10a) \end{aligned}$$

If $\mathcal{E}_g$ be the R.M.S. value of the E.M.F. e_g applied to the grid of the power valve, then $E_g^2 = 2\mathcal{E}_g^2$. Remembering that $\frac{\Psi^2}{\beta} = Q$, and writing

$$A^2 = 2\frac{\mu^2 Q}{\rho^2\beta}\mathcal{E}_g^2\frac{1}{(R + Q + \omega^2\tau L) + \omega^2(L + \tau R)} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

it is seen that we can write (10a) in the form:

$$v = A\,.\,\sin(\omega t - \lambda) \quad \ldots \quad \ldots \quad (12)$$

(the value of λ is not at present important).

Output of Sound W.

W being defined as the mean rate at which work is done on the air by the loud speaker, and remembering that the cone or diaphragm is assumed perfectly rigid, and the suspension free from energy loss, it is clear that this must be equal to the mean rate at which the coil does work on the diaphragm. Now by Equation (4) the force exerted by the coil is :

$$F = m\frac{d^2x}{dt^2} + \beta\frac{dx}{dt} + hx \qquad .. \quad (4)$$

Hence at any instant, the rate of doing work is :

$$F \,.\, v = mv\frac{d^2x}{dt^2} + \beta v\frac{dx}{dt} + hvx.$$

Since $v \equiv dx/dt$ we may write this

$$F \,.\, v = mv\frac{dv}{dt} + \beta v^2 + hx\frac{dx}{dt}$$

W being the average value of Fv, we must integrate this expression over a complete cycle and divide by $2\pi/\omega$. Thus :

$$W = \frac{\omega}{2\pi}\left[m\int_0^{2\pi/\omega} v\frac{dv}{dt} \,.\, dt + \beta\int_0^{2\pi/\omega} v^2 dt + h\int_0^{2\pi/\omega} x\frac{dx}{dt} \,.\, dt\right] \quad .. \quad (13)$$

v and x both being harmonic functions of period $2\pi/\omega$, the first and third integrals vanish when taken over a complete cycle,

$$\left(\int_0^{2\pi/\omega} v\frac{dv}{dt}\, dt = A^2\int_0^{2\pi/\omega} \sin(\omega t - \lambda)\cos(\omega t - \lambda)\, dt = 0\right)$$

And :

$$\int_0^{2\pi/\omega} v^2 \,.\, dt = A^2\int_0^{2\pi/\omega} \sin^2(\omega t - \lambda) \,.\, dt = \tfrac{1}{2}A^2 \,.\, 2\pi/\omega.$$

Hence 13 becomes :

$W = \frac{1}{2}A^2\beta$ and on substituting for A^2 from (11) we have :

$$W = \frac{\mu^2}{\rho^2}\mathcal{E}_g{}^2\frac{Q}{(R + Q - \omega^2\tau L)^2 + \omega^2(L + \tau R)^2} \quad .. \quad .. \quad .. \quad (14)$$

Radiation Resistance.

If $\mathfrak{J}$ be the R.M.S. value of the current i flowing in the coil at any instant, we may apply the term "Radiation Resistance" to a quantity S, defined by the relation

$$W = \mathfrak{J}^2 S \qquad .. \quad .. \quad (14a)$$

From (7a) $\left(mD + \beta + \frac{h}{D}\right)v = \Psi i$

substituting for v from (12), we have :

$$i = \frac{A}{\Psi}\left[mD + \beta + \frac{h}{D}\right]\sin(\omega t - \lambda)$$

$$= \frac{A}{\Psi}\left[\left(m - \frac{h}{\omega^2}\right)D + \beta\right]\sin(\omega t - \lambda)$$

$$= \frac{A\beta}{\Psi}[1 + \tau D]\sin(\omega t - \lambda).$$

Therefore

$$i = \frac{A\beta}{\Psi}[\sin(\omega t - \lambda) + \omega\tau\cos(\omega t - \lambda)]$$

which may be written

$$i = \frac{A\beta}{\Psi}\sqrt{(1 + \omega^2\tau^2)}\sin(\omega t - \lambda').$$

On squaring this and integrating over a complete cycle, afterwards dividing by $2\pi/\omega$, we find the R.M.S. value of i is given by :

$$\mathfrak{J}^2 = \tfrac{1}{2}\frac{A^2\beta^2}{\Psi^2}(1 + \omega^2\tau^2)$$

$$\therefore \quad \mathfrak{J}^2 S = W = \tfrac{1}{2}\frac{A^2\beta^2}{\Psi^2}S(1 + \omega^2\tau^2).$$

But $W = \frac{1}{2}A^2\beta$, and equating these values of W we find that :

$$S = \frac{\Psi^2}{\beta(1 + \omega^2\tau^2)} = \frac{Q}{1 + \omega^2\tau^2}.$$

Substituting $S(1 + \omega^2\tau^2)$ for Q in (14), we find that $(1 + \omega\tau)$ is a factor of numerator and denominator, and after further reduction we arrive at

$$W = \frac{\mu^2}{\rho^2}\mathcal{E}_g{}^2\frac{S}{(R + S)^2 + \omega^2(L - \tau S)^2} \quad (15)$$

Where

$$S = \frac{\Psi^2}{\beta(1 + \omega^2\tau^2)} = \frac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)} \quad .. \quad (15a)$$

and

$$\tau = \frac{m - \frac{h}{\omega^2}}{\beta} \quad .. \quad .. \quad .. \quad (15b)$$

Value of β.

Lord Rayleigh (Theory of Sound, Vol. II, para. 302) has dealt with the reaction of the air on a rigid circular plane disc moving in a closely fitting aperture in an infinite plane baffle, the disc and baffle being the boundary of a semi-infinite mass of gas (*i.e.*, air in our case). Now we have air on *both* sides of the diaphragm and baffle, and as suggested earlier in this paper, if we double Lord Rayleigh's values, so as to allow for air on both sides of the diaphragm, we shall obtain at any rate an approximation to the actual state of affairs for a practical "cone" diaphragm.

We then have:

$$\beta = 2\pi C^2 a\sigma\left[1 - 2\frac{J_1 z}{z}\right] \quad .. (16)$$

where:

$$z = \frac{4\pi}{a} Cf$$

C = Radius of disc in cm.

a = Velocity of sound in air (33,300 cm./sec.).

σ = Density of air (0.00128 gm. per cu. cm.).

Assuming a disc of 20 cm. diameter (*i.e.*, $C = 10$ cm.) as approximately the usual practice, the function β has been worked out from the values of $J_1(z)$ given in Professor G. N. Watson's "Theory of Bessel Functions." ($J_1(z)$ is the ordinary Bessel function of the first kind, of order 1.) The graph of this function has been plotted in Fig. 2, and as tables of Bessel functions may not be immediately available to the reader, who may wish to work out values for himself, four-figure values are given for a few values of z in Table I.

From the ascending series for $\left(1 - 2\frac{J_1(z)}{z}\right)$

$$1 - 2\frac{J_1(z)}{z} = \left[\frac{(z/2)^2}{1^2 . 2} - \frac{(z/2)^4}{1^2 . 2^2 . 3} + \frac{(z/2)^6}{1^2 . 2^2 . 3^2 . 4} \text{ etc.}\right]:$$

it is at once seen that for small values of z, $\frac{J_1(z)}{z}$ is approximately represented by the first term of the series, and will therefore be proportional to z^2, that is to (frequency)^2, and substituting for z in terms of $\omega = 2\pi f$, we find that for small values of z, β is approximately given by $\beta \approx \frac{\pi\sigma}{a} C^4 \omega^2$ .. .. (17)

The approximation is also shown in thick dotted lines on the graph of Fig. 2 (showing $1 - 2\frac{J_1(z)}{z}$ with logarithmic ordinates as well as logarithmic abscissæ) from which it will be seen that it is roughly true up to about $z = 3$ or 4.

For large values of z, $\frac{J_1(z)}{z}$ becomes small compared to 1, and we have very roughly,

$$\beta \approx 2\pi\sigma a C^2 \quad .. \quad .. \quad .. \quad ..(17a)$$

The value of these approximations will be seen subsequently.

(If the graph or table of values of this function is required for a different diameter of diaphragm, say C' cm., we must multiply the value of β by $C'^2/100$, for any given value

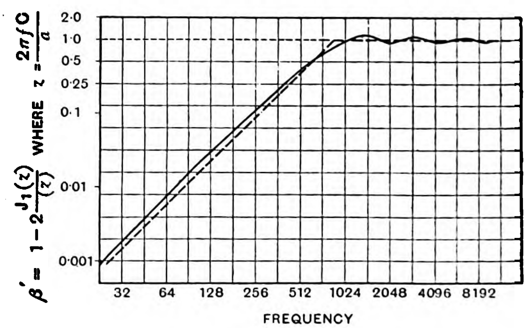

Fig. 2.

of z, and, if we are thinking in terms of frequency, we must remember that the value of z corresponding to any given frequency must be multiplied by $C'/10$.)

Fig. 3 shows the damping coefficient β plotted on semi-log paper. The ordinates are those of Fig. 2 multiplied by $2\pi C^2 a\sigma$.

The Value of m.

The "effective" mass m of the diaphragm or cone is greater than the static mass m_0 (the mass of the diaphragm alone) by a quantity Δm, representing the mass of a quantity of air carried with the diaphragm, which we may call the "adherent air." Lord Rayleigh (*loc. cit.*) has worked out the value of Δm for various frequencies in

terms of $z = \frac{4\pi}{a} Cf$. He arrived at a function of z which he referred to as $K_1(z)$; but this is *not* either of the Bessel functions usually referred to as K functions by mathematicians,

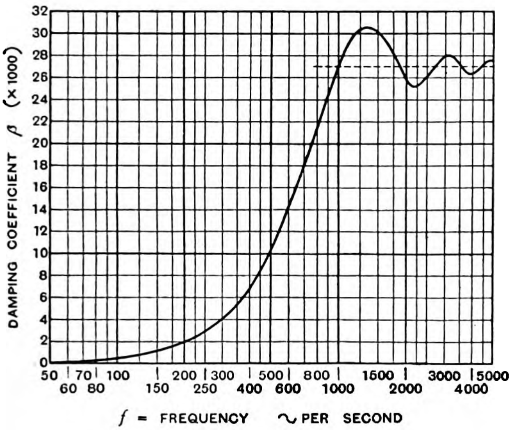

Fig. 3.

in fact although closely allied, it is not a true Bessel function at all (it is not a solution of Bessel's equation). After some difficulty in trying to identify it, the writer referred the question to Professor G. N. Watson, who pointed out that it is closely connected with Struve's functions, usually represented by a (Clarendon) **H**, in fact Rayleigh's

$$K_1(z) \equiv z\mathbf{H}_1(z).$$

This should on no account be confused with the ordinary Bessel function of the third kind usually represented by $H_2{}^1(z)$ and tabulated, for example, in Jahnke and Emde's Funktionentafeln. Values of Struve's functions do not appear to have been tabulated until Professor Watson published them in the tables at the end of his "Theory of Bessel Functions," where they are given to seven places.

Doubling Rayleigh's values (to allow for air on *both* sides of the diaphragm), and using the modern notation for Struve's functions we find that

$$\triangle m = 4\pi\sigma C^3 . \left[\frac{\mathbf{H}_1(z)}{z^2}\right] \quad \ldots \quad \ldots (18)$$

As these tables may not be easily accessible to the reader, values of $\mathbf{H}_1(z)$ as well as of $\triangle m$ are given in the table for a few widely-spaced values of z such as are of importance for calculating $\triangle m$.

The values of $\triangle m$ are calculated for a diaphragm of 20 cm. diameter (*i.e.*, for $C =$ 10, $\sigma = 0.00128$, σ being the density of air, as before) and a graph of $\triangle m$ is given in Fig. 4.

It will be seen that $\triangle m$ is approximately 7 gm. at low frequencies, and begins to drop rapidly about $z = 3$ or 4. This dropping of $\triangle m$ would be very useful in helping to prevent the loss of high notes were it not that the static mass m_0 cannot be made small compared to $\triangle m$. It is with great difficulty that a diaphragm and coil weighing as little as 10 gm. can be constructed, most frequently we find the weight is more like 15 or even 20 gm. For purposes of calculation a 10 gm. diaphragm and coil has been assumed, but it must be remembered that this is rather an ideal to be aimed at than the actual weight of the average existing coil and diaphragm. The "effective" mass, $m = m_0 + \triangle m$ will therefore vary between about 17 gm. at low frequencies to about 10 gm. at the highest frequencies, and the decrease is not sufficient to give us much help with high note reproduction, as will be shown later.*

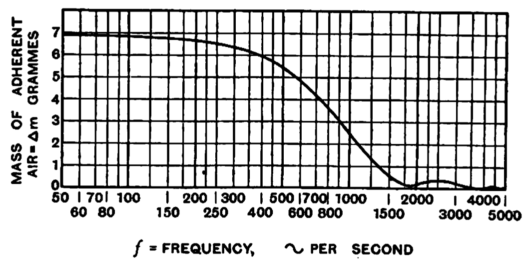

Fig. 4.

The Value of τ.

Numerical values of $\tau = \frac{1}{\beta}\left(m - \frac{h}{\omega^2}\right)$ have been worked out assuming a static mass of 10 gm. for coil and diaphragm, and neglecting $\frac{h}{\omega^2}$ in comparison with m. Owing to the ω^2 in the denominator, the neglected term becomes very small at all but the lowest frequencies, where its influence helps to decrease τ, and therewith the back E.M.F.

* For a discussion of the reaction of the air on a diaphragm, and a *bibliography*, see the Editorials *E.W. & W.E.*, March and April, 1929.

due to motion of the coil in the magnetic field. A small amount of control due to the suspension cannot in practice be avoided, and provided it be not excessive will do good rather than harm. But the presence of h will produce a low-frequency resonance, and we must therefore, by keeping h from becoming too large, make this resonance below the lowest frequency we wish to reproduce. In actual practice, however, even a fairly stiff control does not do as much harm as might be expected; the resonance is in any case heavily damped, and unless the control is intentionally made very stiff (*e.g.*, by excessive stretching of the stockinette or rubber sheet connecting diaphragm and baffle before fixing) it is difficult to detect an objectionable "wolf note."

We may note that as an approximation, we may take m as nearly constant at low frequencies, and since β varies as ω^2 in this region we find that τ varies as $\frac{1}{\omega^2}$, or in other words $\omega^2\tau$ is approximately constant, up to say $z = 3$ or about 500 cycles per second. We shall see that this is very desirable in the interests of keeping up the radiation resistance S, which tends to decrease with increase of frequency. Unfortunately, at the higher frequencies, that is for the larger values of z, we have β nearly constant (see Fig. 2) and the help obtained from decreasing m is not sufficient to compensate for this. If it were possible to make a coil and diaphragm whose weight was negligible compared to $\triangle m$ (say $\frac{1}{2}$ gm. for a 20 cm. diameter diaphragm), the decrease of m would be a great help, but unfortunately this is impossible. We then find that for the higher frequencies τ tends to become roughly constant; this would apply above, say, 700 cycles with our size of diaphragm.

From Equation (15a) we have:

$$\text{Radiation resistance } S = \frac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)}$$

It will be seen that the numerator of this fraction depends only on the coil and induction in the air gap, while the denominator depends only on the cone or diaphragm. The quantity $\frac{10^6}{\beta(1 + \omega^2\tau^2)}$ has been worked out and plotted in Fig. 5 (values also given in table); for any particular coil and gap induction we have only to multiply values of this function taken from the graph by $\gamma^2 B^2/10^6$ to obtain the radiation resistance S. It will be seen from Fig. 5 that S is practically constant up to say 500 cycles, and is not drooping excessively until we reach 1,500

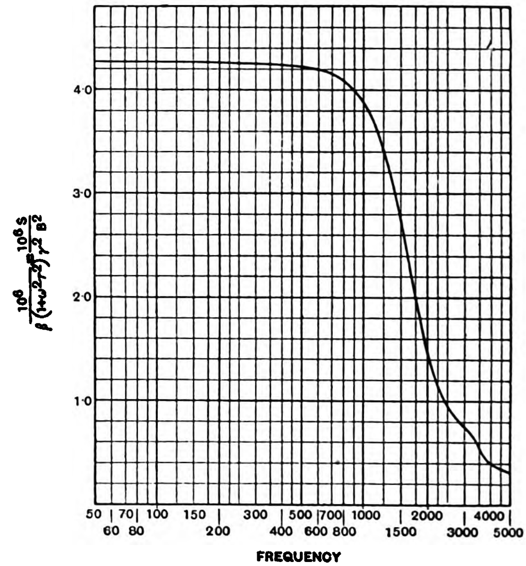

Fig. 5.

cycles (it is doubtful if any but a musician's ear will detect a decrease of intensity of anything less than 2 to 1). But above 1,500 cycles S drops off very rapidly indeed. Now, if we had *constant current* through the moving coil at all frequencies for the same E_g, the sound intensity would be directly proportional to S (actually S multiplied by the square of the current), and it would therefore drop off badly above 1,500 cycles. But in fact, owing to the inductance of the moving coil, the current decreases rapidly with increasing frequency, and it is found that the acoustic output at 1,000 cycles is only about half that at say 200 cycles, making matters much worse than before.

In calculating out S we find that $\omega^2\tau^2$ is always large compared to 1, hence the denominator of (15a) is very nearly equal to $\beta\omega^2\tau^2$. We have seen that at low frequencies β varies as ω^2, while τ varies as $\frac{1}{\omega^2}$, hence $\beta\omega^2\tau$ is practically constant; in fact, if we substitute the approximation of (17) for β we have

$$S = \gamma^2 B^2 \frac{\pi\sigma}{am^2} C^4 \quad \ldots \quad \ldots (19)$$

this approximation being fairly satisfactory up to say $z = 3$, or with our diameter of diaphragm, 800 to 1,000 cycles. For higher frequencies we must use the accurate formula (15a).

Motional Capacity.

Referring to Equation 15, we see that the denominator contains two parts :—

$(R + S)^2$, a (resistance)^2,

and $\omega^2 (L - \tau S)^2$, a (reactance)^2.

S is usually negligible compared with R. Now the term τS occurring in the expression $(L - \tau S)$ represents the effect of the back E.M.F. set up in the coil due to its motion in the magnetic field. The effect of this back E.M.F. is frequently taken account of by means of the so-called "Motional capacity," we must see to what extent this is legitimate and find the value of this capacity, which we shall call K (the symbol C being already in use for the radius of the diaphragm).

Since, as suggested in the last paragraph, $\omega^2\tau^2$ is large compared to 1, we may write $S = \frac{\gamma^2 B^2}{\beta \omega^2 \tau^2}$ nearly, and since $\tau = \frac{m}{\beta}$ we find on substituting these values that $\tau S = \frac{\gamma^2 B^2}{\omega^2 m}$.

Hence the expression $\omega^2 (L - \tau S)^2$ becomes equal to

$$\left(\omega L - \frac{1}{\omega\left[\frac{m}{\gamma^2 B^2}\right]}\right)^2 .$$

But if we wish to represent the effect of the back E.M.F. in the coil by a capacity (the "motional capacity") in series with it, instead of by an addition of $(-\tau S)$ to its inductance, we should find the reactance expression to be $\left(\omega L - \frac{1}{\omega K}\right)$. Hence the motional capacity is seen, by a comparison of the expressions, to be given by

$$K = \frac{m}{\gamma^2 B^2} \quad \ldots \quad \ldots \quad (19a)$$

Now below say 250 cycles, $\triangle m$ does not vary much from its maximum value of about 7 gm. for a 20 cm. diameter diaphragm, so that we can take m as being a constant, *i.e.*, 7 gm. greater than the static mass of coil and diaphragm, that is, the "motional capacity" is very closely a constant quantity below 250 cycles. Above 250 cycles the effect of the assumed K will be very small, it will bear but little relation to the actual facts, but this is of no importance; since the back E.M.F. due to the motion of the coil is negligible, it does not matter whether we represent it accurately by diminishing the coil inductance by τS, or somewhat inaccurately by a "motional capacity" of Equation (19a).

Transfer to Practical Units.

We *measure* R and L in *practical* units, but so far we have supposed we were using *absolute* units. As the practical system is self-consistent, our equations will be equally true if we express everything in practical units, using a suitable conversion factor where necessary. The only quantities whose numerical values are still required which have already been calculated are τ and S. τ is a period of time, expressed in seconds in either system, no conversion factor is therefore necessary; S has so far been expressed in absolute units of resistance, and must therefore be divided by 10^9 to reduce to ohms.

Actual Case Taken.

As it was proposed to make several alternative coils and diaphragms for experimental purposes, it was thought that it would be easier to wind comparatively low resistance coils and use a 25 : 1 step-down transformer. In the particular case given in the graphs the output stage is a pair of B.T.H. B.12 valves arranged in push-pull, with Ferranti transformer. [The B.12 is very similar to the L.S.5a, but from the makers' curves and data the B.12 appears to be suitable for a rather higher anode voltage (425 as against 400), and to have a slightly straighter characteristic, but the two makes of valve are so alike that the figures for the B.12 could be used for an L.S.5a without serious error.]

The constants are, Slope Resistance 2,900 ohms; Amplification factor 2.9. Assuming a moving coil of 100 turns 36 S.W.G. copper, 50 mm. diameter, the D.C. resistance is about 10 ohms, we may allow say 15 for the A.C. resistance (increase due to eddies, etc.). Messrs. Ferranti informed the writer that they had some measurements of the working

A.C. resistance and leakage inductance of an output transformer very similar to that used, as measured on an A.C. bridge at the primary terminals with the secondary short-circuited. By multiplying by $1/\rho^2$ these can be transferred to the secondary, and we find approximately that the resistance is 2.75 ohms and the leakage inductance 616 microhenrys, when so transferred to the secondary. The valve slope-resistance transferred to the secondary is $2 \times 2{,}900 \times 1/25^2 = 9.6$ ohms approximately (the two valves are in series for the audio-frequency currents).

It is estimated that the inductance of a 100-turn coil, 50 mm. in diameter, when in place on the core is about 2,500 microhenrys. Substituting these numerical values in the equations for R and L we have :

$R = 2.75 + 9.6 + 15 = 27$ ohms, to the nearest ohm,

$L = 2{,}500 + 616 = 3{,}116$ microhenrys.

$$S = \text{Radiation resistance} = \frac{\gamma^2 B^2}{\beta(1 + \omega^2\tau^2)}.$$

$$X = \text{Effective Reactance} = \omega(L - \tau S)$$

$$Z \doteq \text{Effective Impedance} = \sqrt{(R+S)^2 + X^2}$$

$$\mathcal{J} = \text{Current in moving coil} = \frac{\mu \mathcal{E}_g}{\rho Z}$$

(for $\mathcal{E}_g = 1$)

$$W = \text{Output} = \frac{\mu^2}{\rho^2} E_g{}^2 \frac{S}{Z^2} = \mathcal{J}^2 S \text{ (for } \mathcal{E}_g = 1)$$

The results are given in Fig. 6, and in the Table.

To see the effect of different number of turns on the moving coil, and of different B, output curves have been plotted for a 50-turn coil with $B = 3{,}000$, and also for a 100-turn coil with $B = 10{,}000$. They are given, together with the output curve for the 100-turn coil and $B = 3{,}000$ repeated, in Fig. 7.

It is found that the instrument for which

TABLE FOR A 20 CM. DISC.

z	f Cycles per sec.	$J_1(z)$	$\mathbf{H}_1(z)$	β abs. units.	$\triangle m.$ gms.	S milli-ohms.	$\omega(L-\tau S)$ ohms.	W microwatts if $\mathcal{E}_g = 1$.
0.16	42.4	0.0797	0.0054	86.3	6.89	94.70	−4.11	6.79
0.2	53	0.0995	0.0085	134.8	6.88	94.72	−2.91	6.86
0.3	79.5	0.1483	0.0190	302.6	6.86	94.70	−1.08	6.93
0.4	106	0.1960	0.0336	536.4	6.82	94.69	−0.10	6.94
0.5	132.5	0.2423	0.0522	835.0	6.78	94.67	+1.01	6.93
0.6	159	0.2867	0.0746	1197	6.73	94.66	1.79	6.91
0.8	212	0.3688	0.1301	2103	6.61	94.61	3.16	6.84
1.0	265	0.4401	0.1985	3238	6.45	94.55	4.39	6.75
1.2	318	0.4983	0.2774	4577	6.26	94.44	5.56	6.65
1.4	371	0.5419	0.3645	6096	6.04	94.31	6.68	6.52
1.6	424	0.5699	0.4570	7766	5.80	94.13	7.79	6.37
2.0	530	0.5767	0.6468	11428	5.26	93.63	9.96	6.05
2.5	662.5	0.4971	0.8632	16260	4.49	92.59	12.63	5.58
3.0	795	0.3391	1.0201	20900	3.68	90.77	15.27	5.05
3.5	927.5	0.1374	1.0916	24880	2.89	88.19	17.89	4.50
4.0	1060	−0.0660	1.0697	27890	2.17	84.29	20.51	3.93
5.0	1325	−0.3276	0.8078	30540	1.05	72.20	25.72	2.79
6.0	1590	−0.2767	0.4782	29490	0.43	55.84	30.93	1.78
8.0	2120	+0.2346	0.4881	25420	0.25	29.28	41.35	0.65
10.0	2650	+0.0435	0.8918	26760	0.29	19.77	51.75	0.31
12.0	3180	−0.2234	0.5839	28000	0.13	14.90	62.15	0.17
14.0	3710	+0.1334	0.4732	26490	0.08	10.53	72.54	0.09
16.0	4240	+0.0904	0.8171	27000	0.10	8.19	82.93	0.06

N.B.—Last 3 columns refer to 100-turn coil 50 cm. in diameter moving in a field $B = 3{,}000$.

The following numerical values were then calculated and plotted for a 100-turn coil of 50 mm. diameter moving in a gap-flux of 3,000 C.G.S. lines per sq. cm., with a diaphragm weighing 10 gm., 20 cm. diameter.

curves are given in Fig. 6 gives volume too great for comfort (even for dancing) in a room 40 × 15 feet, when the R.M.S. value of $\mathcal{E}_g$ is about 100 volts (judged by the anode milliammeter just not flickering, with a grid

bias of 140 volts). Under these conditions the maximum output, at 100 to 150 cycles, is seen from Fig. 6 to be about 7 microwatts per $(\text{volt})^2$, totalling 7×100^2 microwatts, or

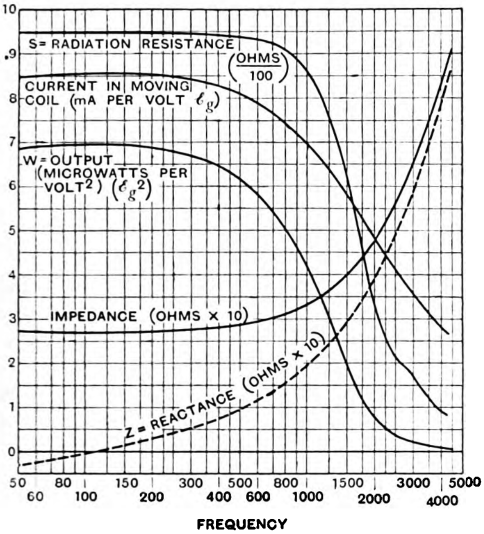

Fig. 6.

about 0.07 watt. It is most surprising what a loud noise can be made for an expenditure of less than a tenth of a watt of actual acoustic energy!

To produce this acoustic energy, the power stage takes about 70 milliamps at 425 volts, say 30 watts, so that looked at from the point of view of ratio of acoustic energy to anode supply energy in power stage, the efficiency is of the order of ¼ per cent. (Note that in both cases we have the best frequency, the power and efficiency at higher frequencies are very much less.) It is interesting to note that the value of K, the "motional Capacity" comes out to be

$$K = \frac{m}{\gamma^2 B^2} = \frac{17}{1500^2 \times 3000^2}$$

$$= \frac{17}{20 \cdot 2} \times 10^{-12} = 0.84 \times 10^{-12}$$

absolute electromagnetic units of capacity. Multiplying by 10^9 to give farads, and then by 10^6 to give microfarads, we find $K = 840$ microfarads. (This value seemed so enormous that the writer spent some time fruitlessly seeking the error, having a vague memory that the usual value of K used by designers was of the order of 1 microfarad. For example, L. E. T. Branch, *Wireless World*, June, 1928, gives a value of about 0.74 microfarad for a particular cone and coil. But it soon appeared, on looking up the article, that this was with the resistances and reactances referred to the *primary* of the output transformer, whereas we are referring to the *secondary*. The value referred to the primary is obtained by dividing K by the square of the transformer ratio (25), giving $\frac{840}{(25)^2} = 1.34$ microfarads, which seems about the sort of value that other workers are in the habit of using.) It is interesting to note that on working out the curve for Reactance by the use of the "motional capacity," results were obtained within 1 or 2 per cent. of the exact values. The effect on the resultant curves of intensity of acoustic output was too small to be shown on the graph. It appears therefore that the approximation obtained by using the "motional capacity" is sufficiently good for all practical purposes.

Design of Moving Coil and of Field-magnet.

First assuming that we are restricted to a 20 cm. diameter cone, let us consider what

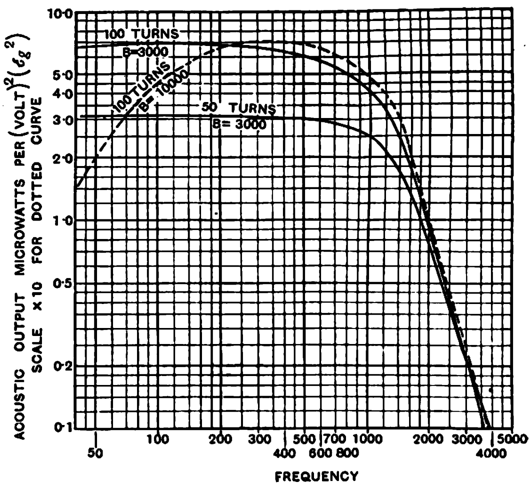

Fig. 7.

will determine the design of the moving coil and field-magnet.

The equations we have to consider are:

$$W = \frac{\mu^2}{\rho^2} \mathcal{E}_0{}^2 \frac{S}{(R+S)^2 + \omega^2(L-\tau S)^2} \quad \ldots \quad (15)$$

and
$$S = \frac{\gamma^2 B^2}{\beta(1+\omega^2\tau^2)} \quad \ldots \quad \ldots \quad \ldots \quad (15a)$$

Numerical calculation of a few cases will show that in any case S is small compared with R, but unfortunately τS is not small compared with L at low frequencies. Still, at first sight it seems that to get great intensity for a given $\mathcal{E}_0$ we should make S as large as possible. This is true within limits, but needs qualification. If we only wished to reproduce *one* frequency, it would be possible to work out the optimum value of S. But unfortunately if we make S too large the back E.M.F. (which is represented by the term in τS) becomes very great indeed at low frequencies, and even when multiplied by ω^2 we find that the denominator of (15) becomes very large, *i.e.*, the impedance of the moving coil at low frequencies goes up. This effect can be seen by comparing the curve of W in Fig. 7 for 100 turns and $B = 10{,}000$ with that for 100 turns and $B = 3{,}000$ (for the latter S is only $(3/10)^2 = 0.09$ of S for the former). The dropping off of W at low frequencies is clearly indicated. We must therefore make S large, but not too large.

Looking at Equation (15a) we see that the denominator is dependent only on the size of the cone, the numerator depending on the coil. If we are to have a given S, does it matter how we obtain it? It is proportional to the square of the product of (length of wire in coil) $\times$ (flux density in gap). There would be an advantage in using a permanent-magnet field, if possible, with which we can easily obtain a flux-density of 3,000 in a 4-millimetre gap 12 mm. long. (A value actually measured with a Grassot Fluxmeter is 3,130 lines per sq. cm.) Can we get an equally good result with $B = 3{,}000$ as with $B = 10{,}000$ by increasing the length of wire on the moving coil? Unfortunately not, for the inductance L in (15) is largely the inductance of the coil, and it is this which cuts down the current in the coil at high frequencies, where we have already lost a lot by the rapid decrease of S. Therefore we must *keep down the coil inductance in the interests of high notes.* This means that we must not use more wire than is absolutely necessary, and must wind it in as *large a diameter coil as possible* (since having the coil diameter and doubling the turns to get in the same length of wire will give us twice the inductance). (Thus the design originated by Dr. McLachlan with a 2in. diameter coil would appear better from the high-note point of view than some of the commercial moving coil loud speakers with a coil diameter of about ¾in.)

Hence, for a given S use the minimum of wire on as large a diameter of coil as possible, in as strong a field as possible.

(It may, however, be possible to use a permanent magnet field with satisfaction, but it means that we must sacrifice volume, or provide a bigger power stage. As a matter of fact a 100-turn 2in. coil in a field of $B = 3{,}000$ worked from two B.12 valves in push-pull with a 25 : 1 step-down transformer will give more volume than can be used in quite a large room, without overloading except in the very loudest passages, and it is debatable whether, given an A.C. supply, the big power valves (filaments run off A.C.) and rectifier to supply 450 volts to their anodes is really more bother than a field-magnet with its accompanying rectifier and accumulator, and a somewhat smaller rectifier for anode supply to say two D.E.5a's, since in any case it is desirable to have a separate rectifier for the power stage, in the writer's opinion.)

Pentodes.—Dr. McLachlan has pointed out that if we had a power valve with an effective slope-resistance that was very high, the effects of inductance in cutting down high notes, and of back E.M.F. in cutting down low notes could be reduced to be nearly negligible, even with a much larger S than usual. The pentode provides the means.

It has been suggested that some method of compensating the inductance of the moving coil should be used. If we had only to deal with a single frequency it would be simple to resonate to it by a condenser shunted across the terminals, but it is obvious that it is impossible to do anything of this sort with a loud speaker which is to reproduce *all* frequencies, as the improvement in one frequency will mean that all other frequencies will suffer badly (it is easy to try this experimentally; the result is musically damnable).

Another suggestion is to think of the moving coil as the primary of a transformer, and provide it with a short-circuited secondary. This may be either attached to and moving with the coil, or it may be fixed to the field-magnet. In the first case, we may wind the moving coil on a closed metal former, or cover the paper former with copper foil before winding.* It can easily be shown that the effect is to increase the effective resistance of the coil, and to reduce its effective inductance. But the mechanical force exerted by the magnet field on the current-carrying former, or short-circuited secondary, is *directly opposed* to that exerted on the moving coil itself (since the secondary balancing current is opposite in direction to the primary current), in fact with a given field-magnet we can show that Ψ^2 (and hence S) varies directly as the "effective inductance" of the coil (in a transformer this would be the leakage inductance referred to primary), hence any compensation by this method can only be partial. It would appear better that the short-circuited ring secondary should be attached to the field-magnet, then any force acting on it will not matter, as it will not oppose motion of the coil; something of this sort is believed to be used in certain commercial instruments. But the metal of the pole-pieces themselves is quite a good conductor, and will act as a short-circuited secondary to some extent, without special provision of a copper ring, hence the improvement resulting from fitting such a ring to an existing moving coil loud speaker is less than might be expected.

The desired end might be attained by means of a compensating winding, consisting of a coil having the same number of turns as the moving-coil but wound upon and fixed to the pole-piece. This would be connected in series with the moving coil, so that the magnetic effect of the current through it opposed that of the moving coil. If L_1 and L_2 be the self-inductances of the fixed and moving coils, and M the mutual inductance between them, the effective inductance of the two coils in series would be

$$L_1 + L_2 - 2M = L_1 + L_2 - 2k\sqrt{L_1L_2}$$

where k is the coefficient of coupling. If we suppose $L_1 = L_2 = L$, which will be approximately true, the effective inductance comes out to $2L(1 - k)$; this will be less than the inductance L of the original coil without any compensating winding provided that k is greater than $\frac{1}{2}$, otherwise the compensating winding will only increase instead of reducing the inductance. The success of the method would then depend upon the possibility of making the coupling coefficient k considerably greater than $\frac{1}{2}$; Mr. E. B. Moullin, who suggested this form of compensating winding to the writer, is doubtful if this large value of k could actually be attained.

With the advent of the pentode, the effect of inductance of the moving coil at high frequencies would be much less marked and no compensation would probably be necessary, or even desirable, in practice.

Variation in Diameter of Cone.

An examination of the curves shows that for a given E_g, W drops at 5,000 cycles to only about 1/160 of the value it had at say 500 cycles. Now $W = \mathfrak{I}^2 S$, and from the curves for $\mathfrak{I}$ and S we see that $\mathfrak{I}$ has dropped to about $\frac{1}{4}$ of the value it had at the lower frequency (and hence $\mathfrak{I}^2$ to 1/16 of its value), while S has dropped to 1/10 of its old value. By the methods suggested above, we might be able to compensate for the drop in I, but no juggling with the *electrical* properties of the moving coil or output stage can alter the shape of the curve for S; this depends on the size of the cone or diaphragm and its weight. The question then arises whether an alteration in the size of the cone is likely to give us a more constant value of the radiation resistance at the higher frequencies. We have seen (Equation 19) that up to about $z = 3$, $S = \gamma^2 B^2 \frac{\pi\sigma}{am^2} C^4$ is a very good approximation, and up to this point the curve of S is very nearly horizontal. Since $z = \frac{4\pi}{a} Cf$, it would appear that we could make the point of departure from a straight line at $z = 3$ occur at a higher frequency, say 3,500 cycles, by reducing C, the radius of the cone, to 1/5 of its original value, 10 cm., giving us a cone of 2 cm. radius. But in reducing C to 1/5th of its original value, we find that S, which is proportional to C^4, is reduced to 1/625th of

* L. E. T. Branch, *Wireless World*, Aug. 1st, 1928, p. 122.

its previous value! The radiation resistance of the speaker is in any case so low that it is a very inefficient machine (say $\frac{1}{4}$ per cent.), so that we cannot afford to cut its efficiency thus drastically. Furthermore, in actual practice there would be physical difficulties in providing efficient baffle action to reproduce low notes satisfactorily. It will be seen, then, that we cannot decrease the diameter of the cone to any great extent unless we are prepared to provide an output stage capable of handling about a kilowatt in order to provide enough sound energy to fill a small room. Increasing the diameter of course makes matters worse so far as high-note reproduction is concerned. A few rough calculations show that values of C from 7 or 8 to 10 cm. (giving a cone of 6 to 8 ins. diameter, say) will probably have to be adopted.

How do we obtain any sensation of high notes at all from such a loud speaker?—If the state of affairs is really as bad as the curves indicate, it seems surprising that we hear any high notes whatever, especially in view of the phenomenon of A. M. Mayer, (*Phil. Mag.*, Vol. II, p. 500, 1876, referred to by Rayleigh, "Sound" II, para 386), namely that if two sounds of different frequency occur at the same time, the higher tends to be obliterated by the lower, although the reverse never seems to occur.

Several suggestions may be advanced.

(a) *Insensitivity of the ear.* A variation of intensity of 4 : 1 is only just noticeable (this can be shown by putting a Moullin voltmeter across the grid leak of one of the valves of an amplifier and regulating the volume control to give readings of ratio 2 : 1 during the tuning-note, when the decrease is barely perceptible; since W varies as the square of the volts this gives a ratio of the intensities of sound 4 : 1. Ask anyone to detune or alter the volume control until the sound is reduced to what he thinks is "about half as loud," and it is found that the Moullin voltmeter readings have a ratio of about 4 : 1; *i.e.*, a variation of intensity in the ratio of 1 to 16 produces the sensation of "about half as loud").

(b) *Want of rigidity of diaphragm.* An actual diaphragm or cone is *not* perfectly rigid, and it appears that this is the real reason why the moving coil speaker produces any high notes at all. The writer must own that he did not appreciate the enormous effect of this want of rigidity of cone until he saw actual experimental curves of output plotted against frequency for several different types of moving coil speaker, shown by the research department of the B.T.H. Co., at the 1929 Exhibition of the Physical and Optical Societies.* It appears that even with a very flexible suspension at the edge of the cone, at all but the lowest frequencies there is superposed on the motion of the cone as a whole an elastic vibration of the material of the cone itself, this effect beginning at as low a frequency as 200 cycles. Illustrations of the calculated modes of vibration in such a case are given by Rayleigh ("Sound," Vol. II, Fig., in para. 206), and some experimental results are illustrated in the Editorial in *E.W. & W.E.* for December, 1927, from experiments by S. Hill on a "Kone" speaker. At the higher frequencies the number of possible modes of vibration (each corresponding to one particular frequency) is very great, and the peaks of the "resonance curve" overlap, it is also probable that due to slight want of exact symmetry the individual modes of vibration are not very sharply differentiated but merge into one another, giving a "flatly tuned" effect, so that the resultant output curve is more uniform than might be expected. In practice, therefore, we actually get the effect of a good high register, although, as might be expected, the exact results depend on the nature of the "want of rigidity," *i.e.*, upon the elastic properties of the material from which the cone is constructed.

(c) *Other effects tending to give high note reproduction.* Eddy currents in the pole-pieces tend to reduce the effective inductance of the moving coil, even without any special damping ring.

The cone has also a certain focusing effect, which is not apparent with a plane disc, giving more prominence to the high notes on the concave side (front). But this effect is frequently exaggerated, for making a cone with a plane face by sticking a circle of paper

* See "An Apparatus for the Projection of Frequency-Output Characteristics," C. G. Garton and G. S. Lucas: *E.W. & W.E.*, Feb. 1929, p. 62, especially Fig. 9.

over the concave side to form the base of the cone does not have much effect in reducing the high notes. The effect would be, no doubt, more noticeable in the open, but in a room where reflection of the sound from walls, etc., takes place there does not seem to be much in it.

Other suggestions. Before the advent of the moving coil loud speaker, searchers after quality frequently used two or more loud speakers together, in order that the deficiencies of one might be covered by the other. With a reed-drive cone and a horn type instrument, quite pleasing results could be obtained. It might be possible to design a horn type speaker specially for the purpose of giving good reproduction on high frequencies, arranging for the resonances which are inseparable from this type to be below say 500 cycles. This might be fed through a high-pass filter cutting off at say 700 cycles, and used in parallel with the moving-coil instrument. Rough experiments with an ordinary horn type instrument seem hopeful, but a specially designed instrument is really necessary.

Another possibility is to interpolate a filter in the middle of the L.F. amplifier, designed to attenuate the frequencies below 700 cycles evenly, with a gradual cut-off from 700 to 2,000 cycles, leaving the frequencies above 200 practically unchanged. This could be done by the use of resistance in conjunction with inductance and capacity in the filter, in order to ensure gradual cut-off.

But, on the whole, the increased output at high frequencies due to elastic vibrations of the diaphragm itself is probably sufficient to do all that is required, in fact the use of a stiff varnished paper for the cone will sometimes appear to overdo it and give too much high frequency. (Ford's thin blotting paper is found very satisfactory for cones.)

Transients.

So far we have only considered the particular integral of (8). There is also a complementary function to be considered. This represents the free oscillations of the mechanical-electrical combined system. The necessary arithmetic is tedious, but without much difficulty it can be shown that no free oscillation will last long, as it will be damped down to 1/100 of its original amplitude in about 2 or 3 cycles, whatever the frequency. There is a small point not often considered, namely, the response of a receiver and loud-speaker system to transient sounds in the transmission (*e.g.*, a revolver shot). So far it will be noticed that we have not bothered about phase-differences, which are in general different for different frequencies. This is because the ear is really a resonating instrument which performs a mechanical harmonic analysis of any musical sounds heard, and is independent of phase. [This, the Helmholtz theory of hearing, has been denied, but the evidence for its substantial accuracy appears overwhelming. A suggestion as to possible errors in the contrary evidence and an account of an experiment may be found in the "British Journal of Psychology" (general section), Vol. XIII, Part I, July, 1922. "A vindication of the resonance theory of audition," by Dr. H. Hartridge and the writer; also "U.S.A. Bureau of Standards, Technical Papers," No. 127, *Effect of Phase of Harmonics upon Acoustic Quality*, by Lloyd and Agnew.]

This is extremely fortunate, for a receiver or transmitter in which any iron is present is bound to produce different phase-changes for different frequencies, as indeed is any transmission line.

But when we come to a transient noise, such as a revolver shot, the effect is possibly different; it is merely shock-excitation of *all* the resonators in the ear, and depends on the steepness of the wave-front. Now if we suppose the transient shock to be harmonically analysed over a long period of, say, a second, we find that the steepness of the wave-front *does* depend on the relative phases of the component harmonics, hence the effect of phase changes in the amplifier is to alter the steepness of the wave front. In general it appears to reduce the steepness, and the reproduction of a revolver shot in the studio comes out of the loud speaker as a duller sound, more like a drum-bang or a slamming door.

Summary of Suggested Method of Design.

In view of the fact that high frequencies are in fact reproduced through resonant vibrations of the diaphragm of which we have taken no account, the practical uses of the analysis would appear to be as follows from the point of view of design.

First, replace the actual arrangement shown in Fig. 8a by that shown in Fig. 8b, in which:

$$\left.\begin{aligned} R &= \left(r_c + r_s + \frac{1}{\rho^2} r_p + \frac{1}{\rho^2} R_a\right) \\ L &= \left(l_c + l_s + \frac{1}{\rho^2} l_p\right) \end{aligned}\right\} \text{.. (Eq. 5)}$$

$$K = \frac{m}{\gamma^2 B^2}$$

(m being the static mass + about 7 gm. for mass of adherent air) (Eq. 19a).

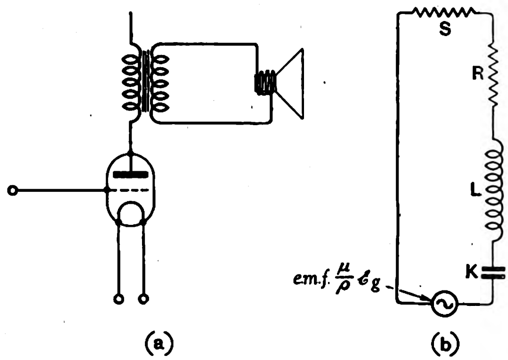

Fig. 8.

Neglecting S, as small compared with R, work out the current I in the circuit of Fig. 8b for an assumed $\mathcal{E}_g$, at various frequencies.

Assuming equation (19) $S = \gamma^2 B^2 \frac{\pi\sigma}{am^2} C^4$,

calculate S, and then $W = I^2 S$. The results will be within a few per cent. of the truth up to the point where elastic vibrations of the diaphragm begin, say, 200 to 300 cycles (for the equations hold up to 800 cycles or so for a rigid diaphragm).

This will give a very fairly true idea of what is happening to the low frequencies, and if we keep the coil inductance down by using a large-diameter coil, and not too many turns, the high frequencies will be brought up by elastic vibrations of the diaphragm.

(With a pentode in the output stage, R is so large compared with L and K that these may almost be neglected.) It is not much use basing design on predictions of what is going to happen to a rigid diaphragm at several thousand cycles, because if the diaphragm *were* rigid we should hear next to nothing.

In practice, it is found that a moving-coil speaker designed from these formulæ gives very satisfactory results.

Marconi Appeals.

Mr. Justice Luxmoore, in the Chancery Division of the High Court of Justice on June 18th, gave his reserved judgment on two important wireless appeals by Marconi's Wireless Telegraph Co., Ltd., against decisions of the Comptroller-General of the Patent Office.

In the first place, he granted the appeal of the Marconi Company against the decision of the Comptroller, which gave to the Brownie Wireless Company a compulsory licence to manufacture valve receiving sets at royalties reduced from the usual basis of 12s. 6d. per valve stage to 10 per cent. on the wholesale selling price of the receiver, subject to a minimum charge of 5s. on the first valve and 2s. 6d. on each additional valve stage included in the apparatus sold.

His Lordship held that there was no case for granting a compulsory licence and he dealt also with various points in connection with the terms of the Marconi Company's General Licence to manufacturers, known as the "A.2" Agreement, and he contended that there was nothing in the various clauses of this agreement which was unreasonable from the point of view of the licensees, and that with regard to the question of the licence agreement providing for the payment of royalties on non-patented articles, that again was not unusual, and in His Lordship's judgment there was nothing unreasonable in a patentee saying:

"I will grant you a licence in respect of my patent, but I want your wholehearted support in the development of my patent. I am only prepared to grant you a licence on such terms as will insure that support."

In the case of the second appeal which was in regard to the granting by the Comptroller of a compulsory licence to the Loewe Radio Co., Mr. Justice Luxmoore held that there was no case for the granting of such compulsory licence as there was no evidence to show that a licence had been refused by the Marconi Company, negotiations between the Loewe Radio Company and Marconi's having been broken off by the Loewe Company.

His Lordship, however, gave as his opinion that a licence on the basis of the payment of royalties would be unreasonable if the amount as fixed by the Comptroller were agreed—namely, 10s. for each triple valve and 7s. 6d. for each double valve, provided the licence was limited to the manufacture of triple and double valves.

In both these cases, therefore, the appeal of the Marconi Company against the decision of the Comptroller of the Patent Office was allowed and the orders of the Comptroller with respect to compulsory licences discharged.

Receiver with Aperiodic High-frequency Amplification.

By M. Von Ardenne.

In comparison with tuned high-frequency amplifiers, in which an oscillatory circuit is necessary for each stage of amplification employed, the aperiodic amplifier with resistance coupling is simpler and, in consequence, cheaper to build. In an aperiodic amplifier it is possible to choose the number of tuned circuits without reference to the number of stages or to the amplification afforded by each stage, and to design the couplings as appears desirable for attaining the required selectivity. In addition, an aperiodic amplifier with resistance coupling, on account of the reduction of the anode current owing to the presence of the anode resistances, offers the advantage of a relatively small anode current, so that even when a large number of stages are employed dry batteries will adequately supply the anode current.

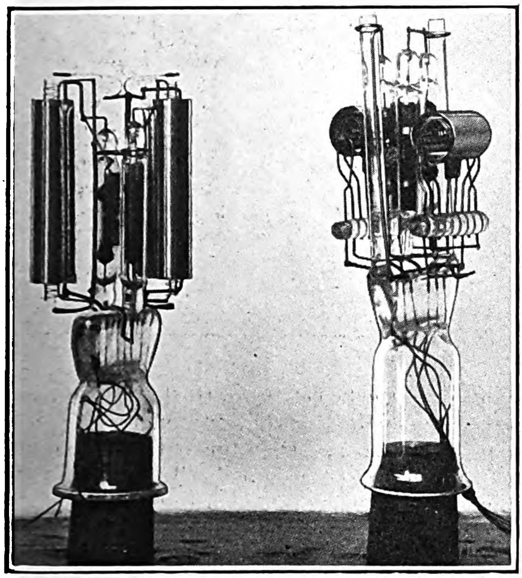

Fig. 1.—*The old (right) and new (left) types of H.F. valves.*

Up to the present, aperiodic amplifiers have been available in the form of the Loewe high-frequency double valve, which made its first appearance on the market about three years ago. Such a valve gives a degree of amplification which is only adequate for long range reception when used in conjunction with an out-door aerial. To provide a receiver sensitive enough for reception with a frame aerial or small indoor aerials, a much greater degree of amplification is necessary. The connection in cascade of a number of valves of the type mentioned is hardly practical, on account of the high current required in the inner grid circuits; in consequence, a new type of multiple valve for high-frequency amplification, which, by employing only a single grid in place of the original two, does away with the inner grid current, has been developed by Dr. Siegmund Loewe and the author.

Compared with the older system, which is shown in the right-hand illustration of Fig. 1, the new system, shown on the left of the same Fig., has far smaller incidental capacities. Not only has it been possible to dispense with the glass rods which, on account of the high dielectric constant of glass, increase the stray capacities very considerably, but in addition all the critical leads have been appreciably shortened. As it is intended that several valves should be connected in cascade, the grid and anode leads in the pinch have been widely separated from one another in the new valve, and are not too close to the battery leads. Although in the new valves no attempt has been made to improve the characteristics by the use of an extra (space-charge) grid, the amplification per stage obtained is a little better than that afforded by the older type, and at the same time the variation of amplification with frequency is, within the broadcast band, smaller.

Fig. 2 shows the various stages in the manufacture of the valve. The connections to the socket correspond with those in the original high-frequency valve, as can be seen from Fig. 3, with the exception that the terminal to which the space-charge grid

was originally connected is now joined to the grid-leak of the second stage. It is therefore possible to use the new high-frequency valve in any receiver in which the older type has previously been employed.

There is one important difference between the two in the fact that in the new valve the couplings are so designed that the valve possesses a high degree of amplification within the broadcast band of wavelengths only. In the new valve *low-frequency amplification does not take place.* This point is of fundamental importance for the construction of multi-stage aperiodic amplifiers, for in this way distortion and low-frequency reaction through the resistance of the source of anode current can be avoided. If the valves, as hitherto, are so designed that low-frequency voltages are transferred to the grid of the next stage, it is a necessary consequence of the presence of stray capacities that the amplification per stage is greater for low frequencies than for high. As soon as small voltage variations occur in the grid circuit of the first valve, whether through microphonic action or otherwise, the high degree of low-frequency amplification gives rise to the appearance of very large low-frequency voltages in the last stage of the high-frequency amplifier; these voltages will in most cases be greater than the high-frequency voltage to be expected at this point. The result of this is that the grid-voltage of the last valve of the high-frequency amplifier swings to and fro over so large a part of the curve that linearity of response can no longer be assumed. In this way the high-frequency voltages are modulated by the low-frequency disturbances, and reception becomes distorted.

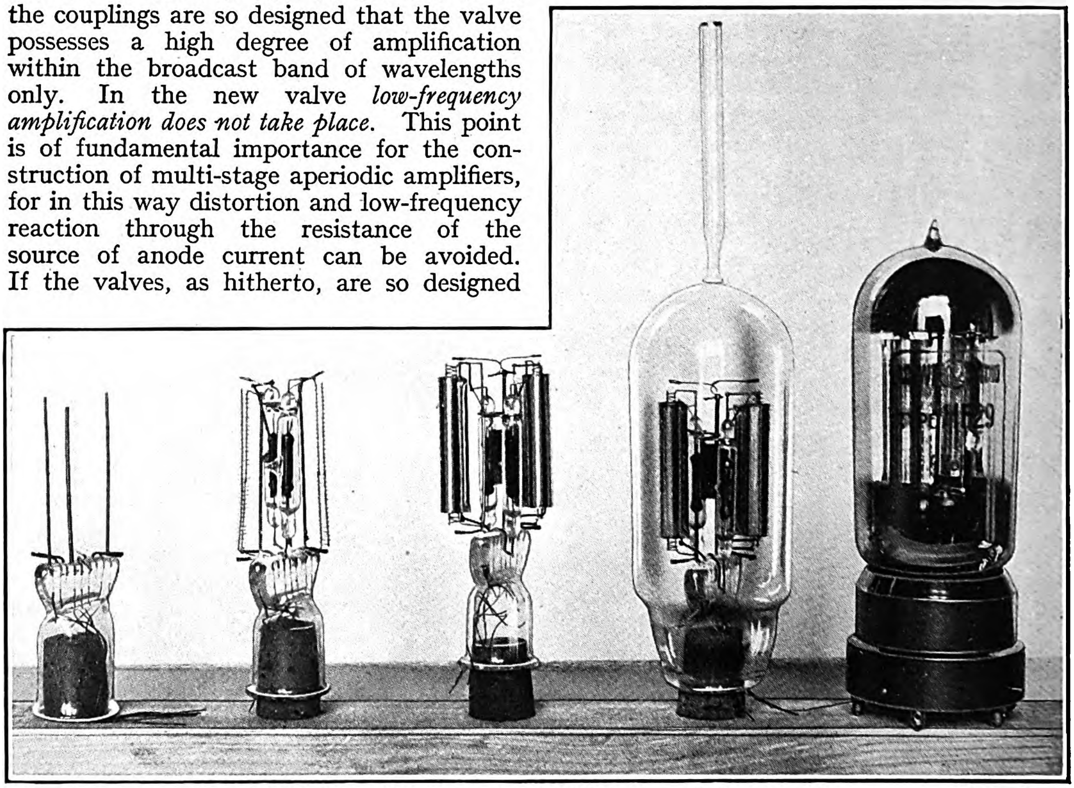

Fig. 2.—*The various stages in manufacture of the new valve.*

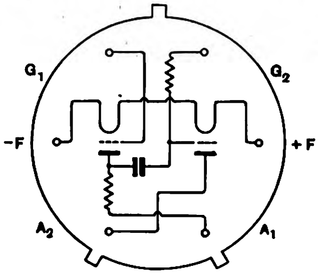

Fig. 3.

It will, therefore, be seen that it only becomes possible to construct a high-frequency amplifier such as that shown in the accompanying diagram, in which six high-frequency stages are connected in cascade, and operated without distortion from a single source of current, when the high-frequency valves amplify but very little at low frequency. In particular the use of mains apparatus for the supply of filament

and plate current to high-frequency double valves is rendered much easier when they are designed on the lines described. In addition the omission of the space-charge grid facilitates considerably the use of battery eliminators with the new aperiodic amplifier.

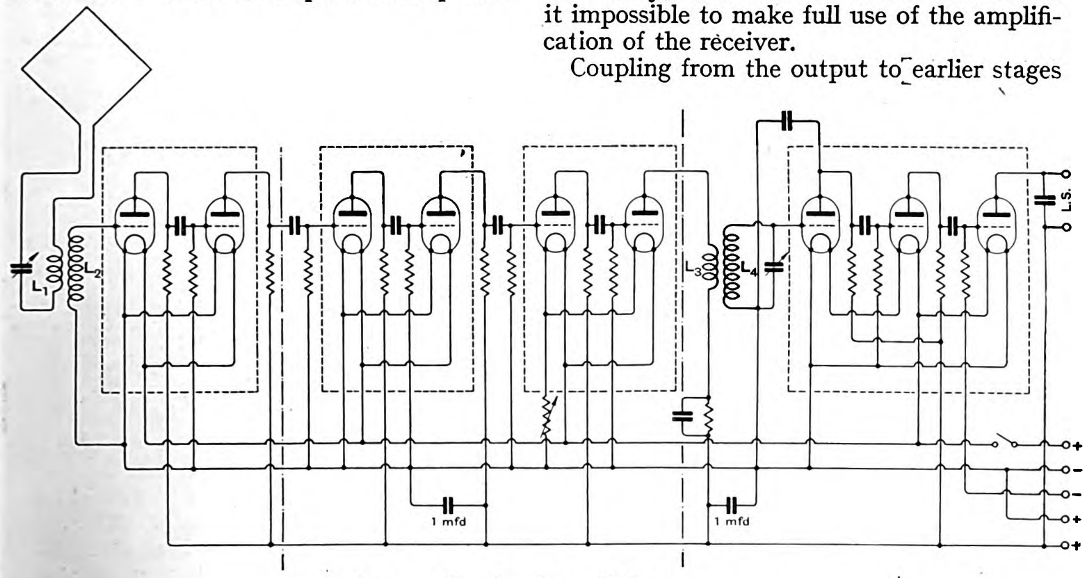

Fig. 4.—*Circuit using 3 H.F. stages.*

If in connecting in cascade several high-frequency valves of the new type care is taken that the parts of the circuit lying outside the valves have but small stray capacities, it is found that the degree of amplification afforded by a circuit which, like that of Fig. 4, makes use of three high-frequency valves, is in the neighbourhood of 5,000 to 10,000 times. Subject to the above proviso the degree of amplification is sufficiently independent of frequency to provide high, even, and adequate sensitivity over the whole of the broadcast band. A circuit such as that of Fig. 4, however, only gives the very high sensitivity required when screening is correctly carried out.

The construction of high-frequency amplifiers with a high degree of amplification makes a special technique of screening necessary. No matter whether this high amplification is obtained with ordinary valves, screened valves, or an aperiodic amplifier, it must constantly be borne in mind that as soon as even a small portion of the high-frequency energy from the output of the amplifier succeeds in getting back to the input or to one of the earlier stages, oscillation will ensue. Such oscillation, which usually sets in long before the amplifier has been brought to its maximum sensitivity, introduces distortion and makes it impossible to make full use of the amplification of the receiver.

Coupling from the output to earlier stages can arise through very different causes, and can be combated in many ways. In all high-frequency amplifiers it is primarily necessary to ensure that there is no coupling between the tuned circuits of the various stages. Magnetic coupling, which is chiefly due to the coils themselves, can be avoided by enclosing these in boxes or thin shells of some conducting material, while capacitative coupling, which mostly occurs be-

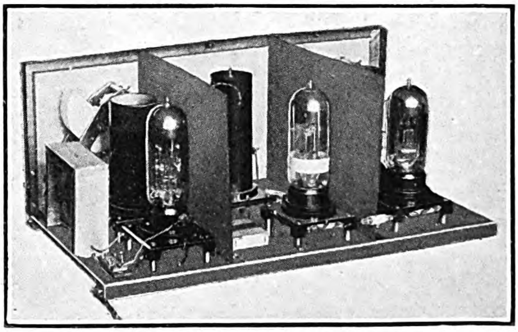

Fig. 5.—*Each stage separately screened.*

tween the tuning condensers, can be prevented by metal caps over the condensers. If we wish to be certain of removing all couplings, it is necessary to enclose each separate stage in a metal box, as has been done, for example, in the receiver illustrated in Fig. 5. By building the whole apparatus in metal boxes, however, the cost is very considerably increased.

For this reason it appeared worth while to investigate more closely the share which each part of the circuit contributes towards the production of the unwanted oscillations. Using only a medium degree of high-frequency amplification, such as is necessary for distant reception with an out-door aerial, complete screening with metal boxes is not usually necessary. It generally suffices for this purpose to cover in the coils and condensers with metal, and in wiring to take care that critical leads are well separated. For frame-aerial receivers one must take particular care that a portion of the high-frequency field set up by the last tuned circuit does not find its way through some small aperture in the screen to the frame.

Since the frame aerial, which is necessarily connected to the input side, obviously cannot be screened,* it is very important in setting up any receiver with a high degree of amplification at high-frequency to ensure that no high-frequency currents or voltages get through into the battery or loud speaker leads. To reduce the likelihood of any such coupling it is advisable in all such receivers to adopt the principle of connecting the frame at one end of the receiver and the batteries and loud speaker at the other. By the use of by-pass condensers and high-frequency chokes, high-frequency currents can be kept completely away from all leads and parts of the circuit which are outside the screening.

Often, however, there are couplings within the receiver itself, even when the successive stages are completely screened from one another. These couplings can mostly be traced back to the high-frequency voltage-drop across the high-frequency resistances of the various connecting wires. To reduce these couplings, the effects of which have

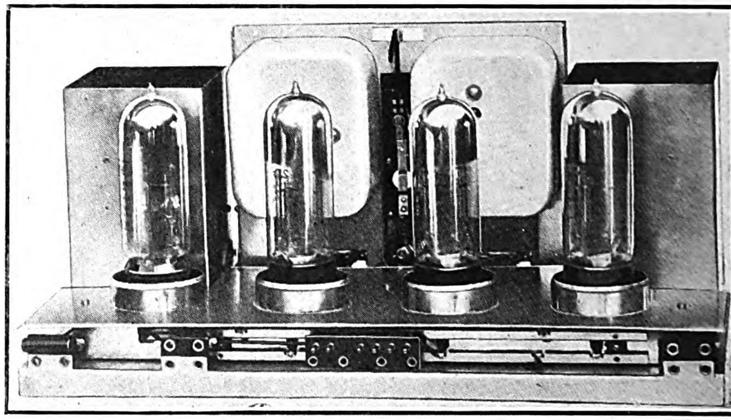

Fig. 6.—*Back view of the new receiver.*

hitherto been seriously under rated, it is necessary, especially in the last stages, where the high-frequency currents are naturally greatest, to connect the anode-leads through condensers to the screening. With very high degrees of amplification, such as are obtained, for example, with the new aperiodic amplifier described below, even this precaution is not enough. To obtain complete stability with such an amplifier it is found necessary to bring all leads through which coupling might be set up to points which are connected through sufficiently large condensers (about 1 microfarad) to the screens, using the shortest possible leads. In cases where the negative filament lead, and with it all filament connections are connected to the screens, and where no grid-bias is used on the high-frequency valves so that these leads also are connected to the screens, we have to regard as critical the anode leads, the positive leads from the source of filament current, and, if four-electrode valves are in use, the leads to the space-charge grids. From the points which are directly connected by condensers with the screens, and at which therefore no high-frequency voltages can arise, the leads to the remainder of the apparatus *must radiate out separately*. In Fig. 6 is shown the

* Only the electrostatic field can be screened.

back of the new Loewe long-range receiver. The arrangement of the valve-sockets and the components used for coupling may be seen from Fig. 7. This arrangement is more certain and cheaper from the commercial point of view than the complete screening in metal boxes shown in Fig. 5.

In order to simplify the operation of a receiver, and to keep the cost of building down, it is necessary to obtain the requisite selectivity with as small a number of tuned circuits as possible. For the solution of this problem it is necessary, with an aperiodic amplifier, to know first of all the resistance on the input and output sides of the amplifier. Since the grid-capacity of the first stage of the amplifier does no more than increase the effective self-capacity of the circuit connected before it, it is only necessary to investigate the ohmic resistance at the input. An ohmic resistance occurs at the input owing to the grid-current. If, as in Fig. 4, no grid-bias is used, but the grid-return lead is simply connected to the negative end of the filament, the grid-current resistance is already in the neighbourhood of some 100,000 ohms. This can be neglected in comparison with the much smaller apparent resistance connected in parallel with it, which is due to the reaction through the grid-anode capacity and to the capacitative load in the plate circuit of the first stage. This apparent resistance has a very great influence on the selectivity in the case of aperiodic amplifiers. For this reason the author has made a number of measurements with the older type of high-frequency double valve, and has taken these results into consideration in designing the new valve.† With the older valve, under normal operating conditions, the apparent resistance in the grid circuit of the first stage amounted to about 21,000 ohms at 500 metres. In this respect the new valve is decidedly better, for at 500 metres its input resistance is about five times greater (100,000 ohms). Since the higher the value of the input resistance, the closer is the coupling that can be employed to attain a given selectivity, the new valve may be regarded as "more sensitive" even when it is worked under such conditions that it gives exactly the same voltage-amplification as the older type.

The resistance at the output side of the amplifier is fixed by the impedance of the last valve. Since this value for the usual high-frequency valve is in the neighbourhood of 10,000 ohms, it is essential to employ at this point a loose coupling to the following tuned circuit. If the couplings at the input and output sides of the amplifier of Fig. 4 are correctly adjusted for the purpose, that circuit provides, in addition to very high sensitivity, a selectivity which, *with only two tuned circuits*, is amply sufficient for the majority of places at which reception is carried out.

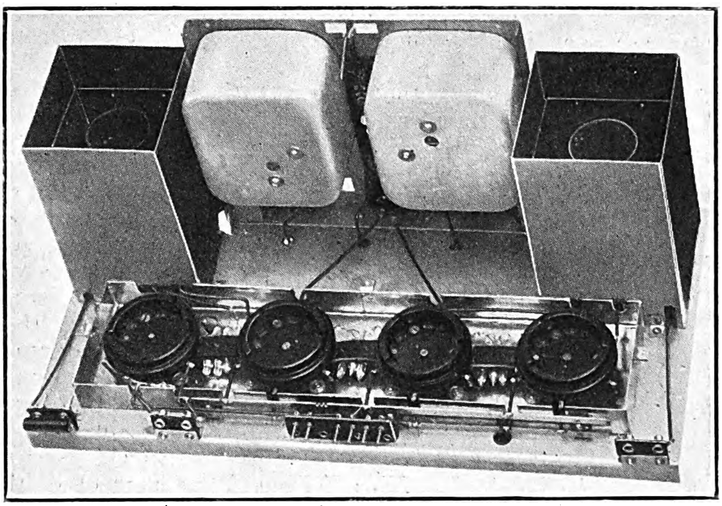

Fig. 7.—*The new receiver showing disposition of parts.*

† M. von Ardenne: "Die aperiodische Verstarkung von Rundfunkwellen," Jahrbuch d. drahtl. Telegt., 1929, April.

Low-frequency Amplification with Transformers.

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MUCH has been written on the subject of low-frequency amplification by means of choke coils and transformers. Several writers have been successful in developing theories, and have furnished us with clear descriptions of the manner in which the L.F. transformer functions. The object of the following article is certainly not to repeat what is already known. but rather to reveal the manner in which the Philips Laboratory at Eindhoven (Holland) is successfully constructing transformers with *very special materials.*

In order to show clearly that the transformer thus produced does really fulfil the reasonable conditions required of it, we shall first of all enumerate these conditions.

Let us start by saying that the properties of *a low-frequency* transformer can only be discussed *in combination with the triode* in the anode circuit of which it is coupled. That will of course be quite clear.

In Fig. 1 the diagram of connections of such a combination is given.

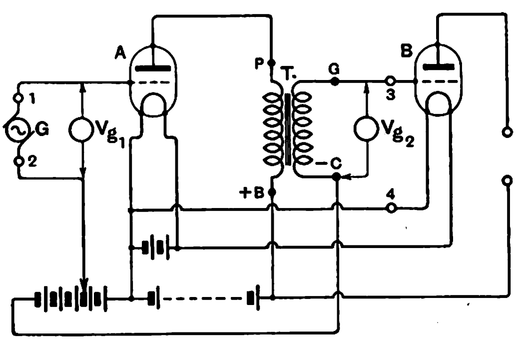

Fig. 1.—*Diagram showing transformer and associated circuit.*

The connection of the triode A with the transformer T forms an "amplification stage." The input terminals of this stage 1 and 2 receive an alternating voltage V_{g_1}, while the voltage V_{g_2} at the output terminals 3 and 4 is handed on to the input terminals of the next stage; that is, between the grid and filament of the triode B.

We say that the stage AT amplifies, when V_{g_2} is actually greater than V_{g_1}. The *amplification* of this stage we can now define as the quotient:

$$\frac{V_{g_2}}{V_{g_1}}$$

The weak high-frequency oscillations, which are induced by the transmitting station in our receiving aerial, after being amplified by a high-frequency amplifier, are converted by the detector valve into waves of audible frequency. The audio frequency alternating voltages produced in this way between anode and filament of the detector valve are usually too weak to work a loud speaker properly when the same is coupled in the anode circuit of the detector valve.

The weak oscillations must therefore now be strengthened with the aid of one or more amplifying stages in order to gain such a strength as will render the voltage between grid and filament of the final valve sufficient to make the loud speaker produce the desired quantity of sound.

The requirements laid down for the amplifying stage are as much quantitative as qualitative. The alternating voltages which are generated between the grid and filament of the final valve must be a true image of the voltages delivered to the input terminals of the amplifier.

If V_{g_1} (in Fig. 1) be any given periodic function of the time, then we can resolve these into the sum of a number of sinoidal voltages, each with a fixed amplitude and a fixed initial phase.

Now we say that the amplification is free of distortion when it satisfies the following conditions:

1. That in V_{g_2} the same components appear as in V_{g_1}.

2. That the amplitudes of the corresponding components are proportionate.

3. That the angles of the initial phases are similar to those of the corresponding components of V_{g_1}.

Differently formulated, the first condition means: "absence of amplitude distortion." The second and third conditions coincide with the requirement: "absence of frequency distortion." A transformer amplifier cannot, from its very nature, completely satisfy these three conditions. But the whole thing can be so well designed that the ideal is very closely approached.

The first condition is as a rule easy to fulfil. The third condition is not however. Fortunately our ear does not notice difference in the phase angles.

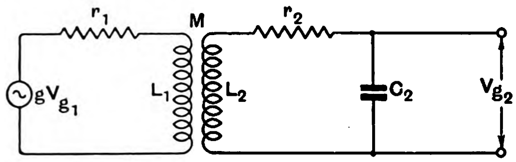

Fig. 2.—*Circuit of amplifier stage.*

The second condition is rather more important. The tone-quality of the human voice or of a musical instrument is determined by the overtones and harmonics and by the amplitudes with which these are produced. In order to preserve this "tone-quality" it is necessary for all the overtones to be amplified proportionately. *This means that the ratio of the amplitudes of a sinoidal alternating voltage before and after amplification must be independent of the frequency of this voltage.*

In order to determine to what extent the transformer amplifier can fulfil this, we must observe the properties of a stage based on the diagram shown in Fig. 2.

It is well known that a triode having any given impedance coupled in its anode circuit is identical with an alternating current generator of which the E.M.F. $= gV_{g_1}$ having the internal resistance $= r_1$. Here g is the voltage amplification factor, and r_1 the internal resistance of the triode used, increased by the resistance of the primary coil. Let the primary self induction of the transformer be L_1, the secondary L_2, and M the coefficient of the mutual induction between the two coils. Then it is well known that owing to the magnetic leakage

$$M^2 < L_1 L_2.$$

We get therefore $M^2 = k^2 L_1 L_2$, in which we call k the coupling coefficient between the two circuits. The resistance of the secondary coil is r_2, while the self capacity of the secondary coil added to the input capacity of the next valve is C_2. The self capacity of the primary coil as well as the capacity between both coils need to be brought into the calculation in the case considered. Also the iron losses need to be taken into account separately, but for simplicity's sake are considered to be included in the other damping resistances.

In order to treat the formulæ simply, we shall introduce some new constants:

$$a_1 = \frac{r_1}{L_1}$$

this represents the primary damping factor;

$$a_2 = \frac{r_2}{L_2}$$

represents the secondary ditto, and

$$\omega_2 = \frac{1}{\sqrt{L_2 C_2}}$$

represents the secondary system's own frequency.

With this data given, we find that, with very close approximation, the following formula is suitable for expressing the *amplification* as a function of the frequency.

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g\dfrac{n_2}{n_1}}{\sqrt{\left\{1-(1-k^2)\dfrac{\omega^2}{\omega_2{}^2}\right\}^2+\left\{\dfrac{a_1}{\omega}-(a_1+a_2)\cdot\dfrac{\omega^2}{\omega_2{}^2}\right\}^2}} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

In the above, $\omega = 2\pi f$, where f represents the frequency. $\dfrac{n_2}{n_1}$ gives the proportion of the number of secondary windings to that of the primary windings. This we will call the "transformer ratio."

The above formula appears somewhat complicated at first, but is simpler than it looks if we take the different terms into account separately.

The denominator is obviously the root of

the sum of two squares. The magnitude of these terms depends apparently on the frequency, and as can be seen from the formula, we can give to the frequency such values that one term or the other vanishes; so that the denominator becomes the same as the remaining term, through which the root form disappears from it.

These two special frequencies, which simplify the amplification formula so much, are calculated by placing the two binomials situated between the brackets one after the other, equal to zero.

The frequencies found from this, which we shall write as ω_0 and ω_s, appear to fix two very important points of the transformer characteristic. By the characteristic of an amplification stage we mean the graphical representation of amplification as a function of the frequency.

It follows, first, then that:

$$\left\{\frac{a_1}{\omega_0} - \frac{a_1 + a_2}{\omega_0} \cdot \frac{\omega_0^2}{\omega_2^2}\right\} = 0 \quad .. \quad (2)$$

and that

$$\omega_0^2 = \omega_2^2 \cdot \frac{a_1}{a_1 + a_2} \quad .. \quad (3)$$

If we substitute this value in formula (1), the amplification appears, in the case of frequency $= \omega_0$, as:

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{1 - (1 - k^2)\frac{a_1}{a_1 + a_2}} \quad .. \quad (4)$$

In the case of the Philips transformer type 4003 combined with valve type A415, for which the transformer is designed, the expressions used have on an average the following values:

$(1 - k^2) =$ approx. 0.01 . $a_1 = \frac{r_1}{L_1}$
$=$ approx. 400 sec.$^{-1}$

$a_2 = \frac{r_2}{L_2} =$ approx. 250 sec.$^{-1}$ $\omega_2^2 = \frac{1}{L_2 C_2}$
$= 42.2 \times 10^6$ sec.$^{-2}$

Continuing, formula (4) becomes:

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{1 - (1 - k^2)\frac{a_1}{a_1 + a_2}} = \frac{g \cdot \frac{n_2}{n_1}}{1 - \frac{4}{650}}$$
$$= \text{approx. } g \cdot \frac{n_2}{n_1} \quad .. \quad (5)$$

while the frequency at which this amplification takes place results from (3), *i.e.*:

$$\omega_0^2 = \omega_2^2 \frac{a_1}{a_1 + a_2} = \text{approx. } 26 \times 10^6$$

from which, $f_0 = \frac{\omega_0}{2\pi} =$ about 800 cycles per second.

Hence we get the following important rule:

In the range of medium frequencies (in the Philips transformer type 4003 about 800 cycles), the amplification which takes place may be easily calculated from the formula:

Amplification = triode amplification factor × transformer ratio.

We term this amplification in the following. 100 *per cent. amplification.*

It follows secondly that:

$$\left\{1 - (1 - k^2) \cdot \frac{\omega_s^2}{\omega_2^2}\right\} = 0 \quad .. \quad (6)$$

and that:

$$\omega_s^2 = \frac{\omega_2^2}{1 - k^2} \quad .. \quad .. \quad (7)$$

This frequency, which clearly is influenced very strongly by the magnetic leakage, we call the "*leakage-frequency*" $= \omega_s$.

Substituting this value in (1), the amplification for this leakage frequency becomes:

$$\frac{V_{g_2}}{V_{g_1}} = g \cdot \frac{n_2}{n_1} \cdot \frac{\omega_2\sqrt{1 - k^2}}{a_1 + a_2} \quad .. \quad (8)$$

If the factors a_1 and a_2 are small, while the magnetic leakage is big (that is to say with k small), it appears from formula (8) that the amplification at the leakage frequency may be many times $g \cdot \frac{n_2}{n_1}$; *i.e.*, many times 100 per cent., so that a high peak appears (see Fig. 3). The frequency at which this leakage peak appears depends (as appears from formula 7) on ω_2^2, that is to say on L_2 and C_2, the secondary self induction and the secondary coil capacity respectively, and also on the size of $(1 - k^2)$, that is, on the magnetic leakage. In the case of the Philips transformer type No. 4003 used in the anode-circuit of the triode A415, it follows that:

$$\omega_s^2 = \frac{\omega_2^2}{1 - k^2} = 42.2 \times 10^6$$

from which it follows that $f_s = \frac{\omega_s}{2\pi} = 10{,}000$ cycles p. sec. The amplification at these frequencies is obtained by substituting the values found for the different quantities in formula (8).

It will be seen that

$$\frac{V_{g_2}}{V_{g_1}} = \text{approx.}\, g \frac{n_2}{n_1}$$

The amplification turns out to be approximately 100 per cent., so that in the case of the transformer stage mentioned the production of a leakage peak is prevented. This is solely due to the fact that the ex-

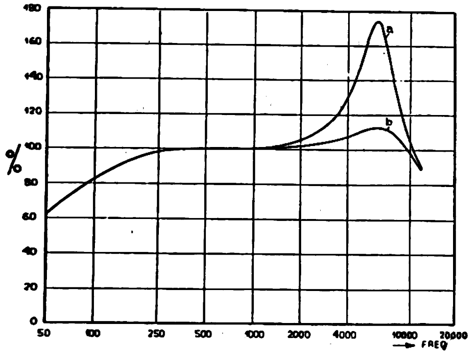

Fig. 3.—*Percentage amplification curve.*

pression $a_2 = \frac{r_2}{L_2}$ has reached the above mentioned value of 250. This is obtained by using for the secondary coil a special nickel-alloy, by which the resistance is brought up to about 60,000 ohms, a value which in combination with the secondary self induction of about 250 henrys accounts for the effective value of a_2. If the secondary coil were made out of ordinary copper wire, the resistance as well as the value of a_2 would diminish to about 1/5 ; on account of which, according to formula (8), a greater amplification than 100 per cent. (*i.e.*, a peak) would necessarily follow (see a, Fig. 3).

Another matter which is of interest in an amplification is the amplification of the lower tones. This is a specially important point in the case of music reproduction, because the harmonics of which a composition is formed are supported by the fundamental tones. If these are too weak the harmonics lack their support, and the music sounds thin and rarefied. But in literature dealing with the subject it is not stated at what low frequencies a proper amplification is desired. In general, it can be said from experience, that reproduction (provided a good loud speaker is used), is sufficiently true if the amplification of voltages having a frequency of 50 cycles per second amounts to 50 to 60 per cent.

For the very low frequencies which we are discussing here, formula (1) can be simplified to:

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{\sqrt{1 + \left(\frac{a_1}{\omega}\right)^2}} \quad \dots \quad (9)$$

In the case of the above-mentioned combination (Philips transformer type 4003 with valve A415), $a_1 = \frac{r_1}{L_1}$ = about 400, so that with a frequency of 50 cycles per second, *i.e.*, $f = 50$ or $\omega = 314$, it follows that:

$$\frac{V_{g_2}}{V_{g_1}} = \frac{g \cdot \frac{n_2}{n_1}}{\sqrt{1 + \left(\frac{a_1}{\omega}\right)^2}} = \text{approx. 60 per cent.}$$

In order to obtain satisfactorily large values for the self-inductances L_1 and L_2 and to give the coupling coefficient k its right value, it is necessary to place the two coils on an iron core.

Most radio transformers on the market contain the ordinary silicon-iron alloy core which is also employed in power transformers and other electrical machinery. The self inductance of a coil which is wound on a core of such material is in a large degree dependent on the amplitude of the alternating flux, that is, on the A.C. voltage on the terminals, and on the magnetisation which is set up by the D.C. flowing in the anode circuit of the triode.

Calculations made concerning this point show that the self-induction varies depending on these very circumstances in the ratio of 1 to 5.

That shows that L_1 (and consequently a_1 in a similar ratio) can change with the amplitude. From formula (9) it is at once clear what the influence on the amplification of low frequencies must be. Those low tones which are already weak are scarcely amplified at all, so that relatively they become still

weaker, and natural reproduction is excluded.

By extensive experiments the Philips laboratory has succeeded in manufacturing for the core a material which is a special nickel-iron alloy, prepared in a very special way, so that all the difficulties met with in the use of normal silicon-iron are overcome. Over and above this, the new core alloy has a much greater permeability than the ordinary iron, so that for a given primary self induction the transformer can be manufactured about three times smaller than if it were provided with the ordinary silicon-iron core.

It is an advantage to have the ohmic resistance of the primary as small as possible. The normally used enamelled copper wire has only a low elasticity, so that it often breaks when being wound on the coil and requires joining repeatedly. These unwanted joints are weak points. Corrosion is often set up by chemical action and consequently breaks occur.

For these reasons the primary coil of the Philips transformer type 4003 is made of a special silver alloy wire having a suitable elasticity for winding and having no tendency to corrode. The components of the alloy are such that the specific resistance of it is approximately that of copper.

The effective design of the Philips transformer type No. 4003 is based on the use of three special materials, as follows :

(1) In the *core* the special *nickel-iron* alloy, which, notwithstanding the small dimensions of core and primary coil, provided a great primary self-inductance, is not, as in the case when ordinary silicon-iron is used, dependent on the amplitude of the voltages to be amplified.

(2) In the *secondary coil* the *nickel-alloy* which prevents a leakage-resonance peak in the curve. Owing to the magnetic properties of this alloy the secondary resistance increases very much with higher frequencies, so that according to formula (1) the amplification falls off rapidly with frequencies above the leakage-frequency. The special nickel wire used for the secondary coil possesses a considerable strength for winding purposes and is also proof against external chemical action.

(3) The special *silver alloy* used in the *primary* has a low resistance, and at the same time a high mechanical strength.

Some Additional Notes on Low-frequency Amplification by Means of Transformers.

Readers who ask themselves the question why the transformation ratio cannot be raised higher than 1 : 3 only need to apply formulæ (7) and (8) in conjunction with (9). In order to get a satisfactory amplification of low tones, $a_1 = \frac{r_1}{L_1}$ must have a definite value. The value of r_1 being fixed by the triode chosen, L_1 follows as a result.

A larger transformation-ratio than that in the present case means an increase of L_2. The coil-capacity C_2 cannot be made less than a fixed amount (about $100\mu\mu F$), from which it necessarily follows that $\omega_2^2 = \frac{1}{L_2C_2}$ is decreased by increasing the transformer ratio.

The value of $(1 - k^2)$ of formula (7) also cannot be made smaller without making the transformer bigger, more intricate, and consequently more costly. Most transformers made by manufacturers have $1 - k^2 =$ about 0.02 ; Philips type 4003 has $1 - k^2 = 0.01$.

In these cases the leakage-resonance-frequency will in consequence be lower. According the formula (8) the amplification at this frequency also falls off, which means that a greater transformation-ratio than is used in type 4003 will give the following results :

(1) A decrease in the amplification of the higher tones, if the increase is obtained by means of an increase of L_2, or :

(2) A decrease in the amplification of the lower tones, if the higher transformation ratio is obtained by diminishing the number of primary windings, and thus L_1.

A given triode such as Philips type A415 valve requires a certain value of the primary inductance, *i.e.*, the core and the number of primary windings, to provide a sufficient amplification of the lower frequencies.

On the other hand, the transformation ratio and consequently the number of secondary windings, together with the resistance of the secondary, are governed by the amplification required of the higher frequencies.

The Transformer Characteristic.

To draw right conclusions from a transformer-characteristic it is necessary to know the data of the triode valve in the anode circuit of which it works.

Since a transformer-stage is a voltage amplifier, we have to consider the ratio of the A.C. voltages on the grids of two consecutive triodes as a function of frequency; *i.e.*, the ratio $\frac{V_{g_2}}{V_{g_1}}$ in Fig. 1.

The voltmeters with which the voltages are measured should give no load, neither

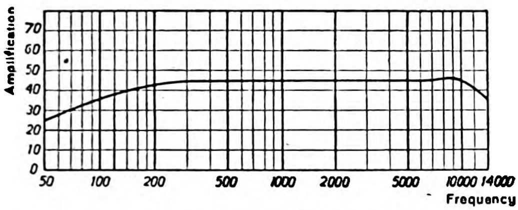

Fig. 4.—*Characteristic of Philips transformer.*

capacitative nor resistive; otherwise the transformer will not be functioning under normal conditions.

Most useful for this purpose are "valve-meters" working with anode-detection, provided that the following conditions are kept to:

(1) Input condenser used in all cases.
(2) No grid currents allowed to flow.

The diagram of connections for these measurements is shown in Fig. 1. In this G is a generator of sinoidal voltages of audible frequencies, while V_{g_1} and V_{g_2} are triode-voltmeters.

The characteristic of the Philips transformer type 4003 as given in Fig. 4 used in combination with the A415 type valve is obtained in the way described above.

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The Moving Coil Loud Speaker.

By H. M. Clarke, B.Sc.

THE problem of obtaining uniform response from the moving coil loud speaker has of late attracted considerable attention from the technical experts, and much has recently been published on the subject. The author's present object is to suggest a method for controlling the electrical impedance and the motional impedance of the instrument so as to obtain any required characteristic change with frequency.

It is proposed to consider the final or output stage only and in this case it may be said that the response frequency characteristic is affected by five primary phenomena. The first phenomenon is the waveform of potential difference applied to the grid of the output stage and is hereafter assumed to be a faithful representation of the waveform of the sound which it is desired to reproduce.

The second is the output characteristic of the valve or valves to the anode circuit of which the loud speaker is connected.

The third is the electromagnetic characteristic of the loud speaker circuit when no sound is being emitted.

The fourth is the physical characteristic of the moving system of the instrument; the fifth being the acoustic characteristic of the atmosphere and auditorium.

Of these, the first can be controlled independently of the others. The last will be taken as referring to a semi-infinite medium depending only upon the effective area of the diaphragm, in which case, as soon as a particular moving system has been constructed and suspended the effect of the atmosphere is predeterminate, and, moreover, the fourth is settled, in that the mechanical driving force required to produce a certain acoustic effect at any frequency is fixed.

The crux of the matter is how to control the driving force so as to give the loud speaker the correct sound-frequency characteristic. This force is proportional to the current flowing in the moving coil; there is, therefore, a certain relation between current and the desired acoustic effect. With the given grid voltage waveform, however, the current which flows in the instrument is mainly determined by the second and third of the primary phenomena mentioned above, namely, the anode characteristic and the electromagnetic characteristic of the instrument. The former does not vary with frequency, but the latter varies considerably.

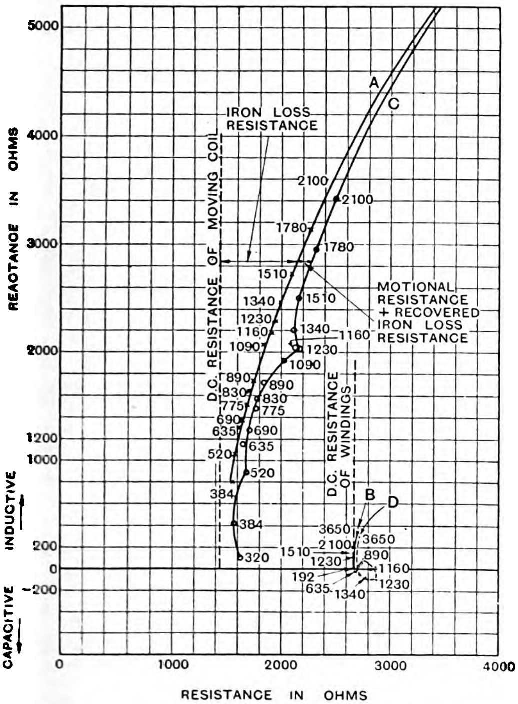
It is possible to make the latter effect negligible by having a moving coil with a resistance which is low compared with the valve anode resistance, but it must be remembered that the impedance of the moving coil rises rapidly with frequency, and it is necessary to have the impedance at a high-frequency small compared with the anode resistance. In these circumstances the current is constant and very much below that for maximum power output of the valve. This inefficient use of the output stage is not the worst feature of such control. It is inevitable that the suspension of the moving system should impose natural frequencies of vibration upon the moving coil in such a way as to vary the motional impedance of the instrument over wide limits. At one of these resonant frequencies much less current is required to produce the same acoustic effect as that required at a non-resonant frequency.

An obvious way to correct this is to shunt the instrument with a filter circuit of such a resistance as to by-pass the current to the desired extent. Unfortunately, the shunting effect of the filter circuit does not decrease with increase of frequency rapidly enough if, as happens to be the case, the impedance of the instrument rises rapidly. The filter circuit can only be used with good effect if the impedance of the instrument does not vary with frequency. The present object is to indicate a method of obtaining a constant impedance non-inductive instrument which lends itself to damping with filter circuits, which allows of the use of the maximum power output available, and which may be

controlled externally to obtain any required response characteristic.

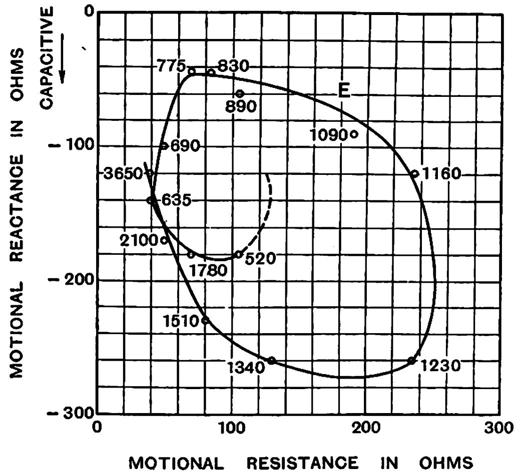
Curve *A* shows the variation of impedance of a typical moving coil instrument with frequency. This curve was taken at constant current with no steady magnetic flux in the air-gap and therefore the instrument was silent.

The points to notice are the increase of resistance, and the increase of impedance, with frequency. The increase of resistance indicates hysteresis and eddy current losses in the iron near the gap, and is undesirable, since the power available in a given output circuit is limited, if for no other reason. The three-fold increase of impedance between 0 and 2,100 frequency shows that the current-frequency characteristic of a valve



Constant current vector impedance-frequency curves of moving coil loud speaker, 1,400-turn moving coil.

output circuit containing this instrument will be much modified, unless the output valve has a high internal resistance. The increase of resistance can be reduced to a great extent by laminating radially the iron near the air-gap, but although this eliminates eddy current losses, it does not affect hysteresis; nor does it reduce the reactance of the moving coil, which is the chief factor in the rise of impedance.



Motional impedance uncompensated; vector difference of impedances with and without D.C. field.

Hysteresis, eddy currents and self-induction can be reduced to a negligible quantity by employing a compensation winding, which is now offered as the solution of the problem of loud speaker response control.

The arrangement used by the author was to wind on the inner pole half as many turns as on the moving coil, and to insert a coil (with half as many turns as on the moving coil) in the air-gap outside the moving coil and fixed to the outer pole. The result is that the *moving* coil is evenly flanked by as many *fixed* turns as itself contains. These windings were then connected in series in such a direction that the fixed windings magnetically opposed the moving coil.

Curve *B* shows the test results over the same range of frequency as in Curve *A*.

The points are so close together as to be almost unplotable to the same scale as curve *A*, but it is necessary to show them to the same scale in order to bring out clearly the improvement in power factor and in the impedance characteristic brought about by compensation. Curves *G* and *H* are enlargements of *B* and *D* with an offset origin.

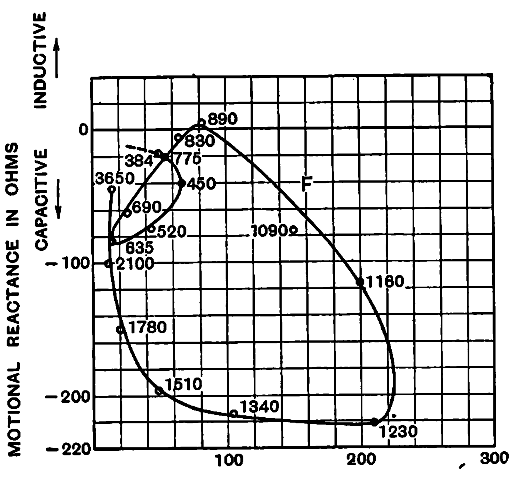
Of course, in the compensated instrument there is double the amount of copper resist-

ance, but it will be seen that the uncompensated instrument reaches this value before 3,000 frequency. The principal feature is that where curve *A* shows an increase of 230 per cent. in impedance, curve *B* shows only 4 per cent. for the same range of frequency.

It should be mentioned that the curves were made on the same instrument, the compensation windings being disconnected to obtain curve *A*.

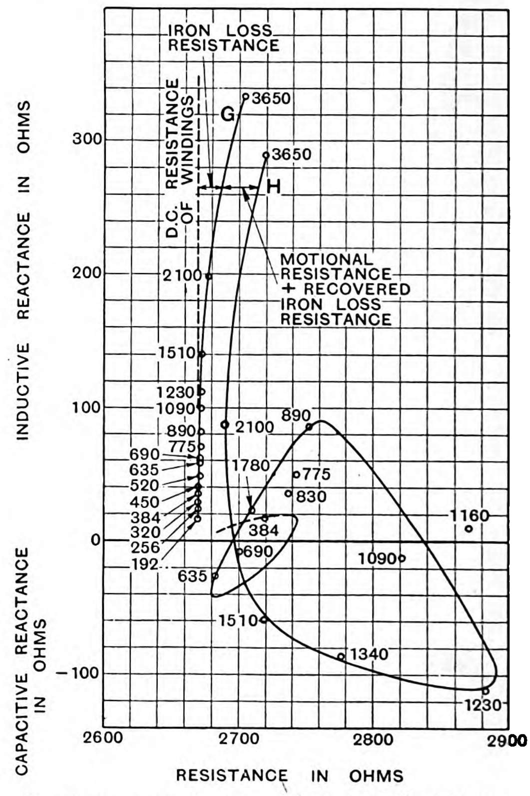
While it is obvious that with constant current the impedance may be kept fairly constant when the direct current field is zero, it is necessary to know the effect of this field to obtain the motional characteristic. It is here that the individuality of the particular instrument asserts itself and demands special consideration.

When the air-gap contains no steady flux and when, therefore, no sound is being emitted, it does not matter what means are used to locate the moving coil in the gap. Therefore curve *A* is typical of an uncompensated instrument and curve *B* is typical of the same instrument when compensated. Methods of suspension and dynamic resonances do not enter into the question. Curves *C* and *D*, however, apply only to the particular instrument used by



Motional impedance compensated ; vector difference of impedances with and without D.C. field.

the author, since they refer to operating conditions, which are affected by the method of suspension. At the same time, the forms of these curves may be taken to be typical of what happens in most cases, modifications being introduced by the mass of the moving parts, the area of the dia-



Constant current vector impedance-frequency curves. Curves B and D enlarged and with offset origin. G Field off—compensated. H Field on—compensated.

phragm, the resonances of the suspension, the damping of the suspension and air friction. Curves *C* and *D*, then, are typical impedance-frequency characteristics with main field energised, uncompensated and compensated respectively.

The cusps on *C* indicate resonances with the natural frequencies of suspension and correspond with loops in curve *D*. These loops are more clearly shown in curve *H*. The irregularity of the latter compared with the smoothness of *C* is more apparent than actual and is brought about by the fact that the uncompensated curves are spread over a larger range of values. That the irregularity is common to both can be seen

when motional impedance curves are plotted. These are given in curves E and F, and are obtained by taking vector differences of pairs of impedances at the same frequency, field on and off. Curve E is the uncompensated case, curve F the compensated.

More points are necessary to establish E and F with precision, and the linking-up shown is intended to convey the general form only. It is not intended to use these curves otherwise than to show that the motional impedances differ but slightly in the two cases, that compensation has not been materially affected by the presence of the direct current field, and that the ratio of maximum to minimum motional resistance is appreciably the same in the two cases.

It is obvious that the compensated instrument will take almost constant current at all frequencies if connected in the anode circuit of an output valve. Now since curve F represents motional impedance at constant current, it is clear that the horizontal component of this impedance is to a certain scale a measure of the motional power input to the moving system. It will not be wholly available for sound production, but the immediately important point is that it varies considerably, in the present case about sixteenfold. If the instrument be now shunted with a filter circuit resonating at about 1,250 frequency, and having a resistance sufficient to reduce the current in the instrument to one-quarter of its value when unshunted, the motional power input curve becomes almost uniform over the working range, so far as that particular resonance is concerned. The other resonances might be treated in the same way.

The resistance of the filter circuit depends upon the output anode resistance as well as the instrument resistance. If the latter is made equal to the former, or so nearly equal as to affect the current when the series impedance in the anode circuit varies, the valve current will rise at resonance owing to the pronounced shunting effect at that frequency. This can best be illustrated by the use of symbols.

Let R_1 represent the resistance of the instrument, including an amount R_2, the motional resistance at resonance, and R_2^1 the motional resistance remote from resonance. Let R_3 be the resistance of the filter circuit at resonance, and R_4 the internal resistance of the output valve.

Then the current at a frequency remote from resonance $\propto \dfrac{1}{R_1 + R_4}$ and the motional power $\propto \dfrac{R^1_2}{(R_1 + R_4)^2}$.

The current at resonance $\propto \dfrac{1}{R_4 + \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_3}}}$

i.e.

$$\frac{1}{R_4 + \dfrac{R_1 R_3}{R_1 + R_3}}.$$

Of this current, only $\dfrac{R_3}{R_1 + R_3}$ passes through the instrument, so that the instrument current at resonance

$$\propto \frac{R_3}{R_1 + R_3} \times \frac{1}{R_4 + \dfrac{R_1 R_3}{R_1 + R_3}}$$

i.e.

$$\propto \frac{R_3}{(R_1 + R_3)\, R_4 + R_1 R_3},$$

and the motional power

$$\propto \frac{R_2 R_3^2}{\{(R_1 + R_3)\, R_4 + R_1 R_3\}^2}.$$

If this is to equal the power at non-resonance, then $\dfrac{R_2^1}{(R_1 + R_4)^2}$ must equal

$$\frac{R_2}{\left\{\left(\dfrac{R_1 + R_3}{R_3}\right) R_4 + R_1\right\}^2}$$

Suppose $R_2 = a^2 R_2^1$, then $(R_1 + R_4)$ must equal

$$\frac{1}{a}\left\{\left(\frac{R_1 + R_3}{R_3}\right) R_4 + R_1\right\}.$$

If R_1 is made equal to R_4, then 2 must equal

$$\frac{1}{a}\left\{\frac{R_1 + R_3}{R_3} + 1\right\} \text{or } R_3 = \frac{R_1}{2(a-1)}.$$

Since, in the present case, $R_2 = 16 R_2^1$, a equals 4, and it will be seen that R_3 should be one-sixth of R_1. If R_4 is large compared with R_1, R_3 should be one-third of R_1 to give the same shunting effect.

This arrangement produces an instrument and damping circuit arranged so as to give

constant motional power input with varying frequency, provided that the choke and condenser of the damping circuit be chosen to give the necessary rate of change of impedance of the damping circuit with frequency. Other characteristics may be obtained by suitably adjusting the damping circuits or by shunting the compensation winding in different ways in conjunction with a change in the number of compensation turns, and it should not be difficult to get practically any response curve desired.

In conclusion, it may be remarked that while compensation can do little towards increasing the facility with which the moving parts take up a particular motion, the improvement of power factor is a step in the right direction in that it facilitates the rise of the current to its full value. With regard to a transition from one frequency to another, or from one amplitude to another, the shunting circuit provides means of dissipating electrically the unwanted kinetic energy and so of cutting down the period of time during which transients are maintained.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

On the Writing of Scientific Papers.

To the Editor, E.W. & W.E.

SIR,—Mr. F. M. Colebrook's excellent article omits one important point often overlooked by scientific writers, viz., the choice of a suitable title. It is presumed that every scientific paper is written with the idea that it may be used for future reference; the title should, therefore, be chosen with a subject-matter index in view.

Many scientific papers, especially those in German technical publications, have titles which may fitly be described as "verbal processions" in which it is difficult to discover the key-words under which they might be looked for in a reference index.

As one who has to keep up several of these indexes I am emphatically of opinion that scientific titles should be as short and concise as possible, and that the key-word should come, if not absolutely first, at all events in a forward and conspicuous position.

W. H. MERRIMAN.

Frequency Modulation.

To the Editor, E.W. & W.E.

SIR,—In his letter, published in the May issue, Mr. Holmblad appears to be in error in his conception of the frequency modulation system, or at least in the formula he employs in translating that system into a mathematical expression. The formula he uses is

$$i = A \sin (\omega t + k \sin mt) \quad \ldots \quad (1)$$

where A is the constant amplitude, ω the cyclic carrier frequency, m the cyclic signal frequency, and k a modulation constant.

The best way of approaching the subject is to consider first the expression for an unmodulated carrier wave

$$i = A \sin \omega t \quad \ldots \quad (2)$$

It includes two parameters, A representing amplitude, and ω cyclic frequency. When A is given a periodic variation and ω kept constant we have the ordinary amplitude modulation; and when A is kept constant and ω has a periodic variation, frequency modulation arises. Now, if ω is given a periodic variation between limits $\omega + k$, $\omega - k$ and if this cycle of variation is repeated $m/2\pi$ times per second, then to obtain from (2) the expression for frequency modulation we have to substitute $\omega + k \sin mt$ for ω. This gives

$$i = A \sin t\,(\omega + k \sin mt)$$
$$= A \sin (\omega t + kt \sin mt) \quad \ldots \quad (3)$$

It will be seen that (3) differs from (1) in having an extra t factor in the second term.

The method employed by Mr. Holmblad for splitting his expression (1) into a series of side-band terms is not applicable to the expression (3), and I have not succeeded in devising or discovering an alternative method.

The conclusions arrived at in Mr. Holmblad's letter are, of course, invalidated by his initial error; but I hasten to add that this letter is not intended to justify the claim made on behalf of the frequency modulation system that it requires a band of only 100 or so cycles for speech transmission. It sounds too good to be true. Perhaps one of your readers may be able to split the expression (3) into the sum of a series of simple sine terms. For this purpose it is legitimate to assume that k and m are both small compared with ω.

G. H. MAKEY.

The Patent Office, W.C.2.

Abstracts and References.

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PROPAGATION OF WAVES.

SUR LES PROPRIÉTÉS DIÉLECTRIQUES DES GAZ IONISÉS DANS LES CHAMPS DE HAUTE FRÉQUENCE (On the Dielectric Properties of Ionised Gases in H.F. Fields).—H. Gutton. (*Bull. d.l. Soc. franç. d. Phys.*, 1st February, 1929, p. 30S.)

An application of the author's previous work (April Abstracts, p. 204) to a theory of the propagation of waves in the upper atmosphere, which demands neither discontinuity of ionisation nor the existence of several layers. "The band of absorption corresponds to an ionisation which is greater in proportion as the wave is shorter; and corresponds therefore to a layer proportionately higher. At this layer there is produced a reflection of metallic nature, which is the more perfect the higher the layer and the less the pressure—since the damping of the electronic oscillations is less. Short wave reflection is thus better than long wave. It is natural to suppose, since atmospheric ionisation is a solar effect, that this ionisation is greater by day than by night, so that by day the reflecting layer is lower. One imagines that for waves of a few hundred metres [under these conditions] the damping almost completely suppresses reflection, and daylight range is less than night range. For shorter waves, some dozens of metres in length, the daylight range retains a higher value since reflection still takes place at very high levels."

SUR LA CONSTANTE DIÉLECTRIQUE DES GAZ IONISÉS (The Dielectric Constant of Ionised Gases). —H. Gutton. (*Comptes Rendus*, 6th May, 1929, V. 188, pp. 1235–1237.)

Developing his previous work on the R.F. resonances in ionised gases, the writer arrives at an equation representing the variations of the dielectric constant as a function of the number of ions for a pulsation ω:

namely $$K = 1 + \frac{0.278 \times 10^{10} N}{35.5 \times 10^{10} N^{3/4} - \omega^2}$$

This formula allows the value of ionisation to be found corresponding to resonance with any pulsation ω. Thus for $\lambda = 248.7$ m., resonance is produced for an ionisation $N = 1.9 \times 10^8$ electrons per cm^3.

TRANSIENT EFFECTS WITH IONS OF LOW MOBILITY. —H. P. Walmsley. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 365.)

With a variable ionisation, the currents produced show a lag with time behind the changes producing them. With mobile ions this effect is negligible, but it is of importance with ions of very low mobility. Any change causing a redistribution of such ions in the electric field which is employed to measure the currents produces transient effects which may be comparable in magnitude to the currents measured, and which persist for an appreciable time.

AN INVESTIGATION OF SHORT WAVES.—T. L. Eckersley. (*E.W. & W.E.*, May, 1929, V. 6, pp. 255–260.)

Long abstract, illustrated, of the I.E.E. paper referred to in June Abstracts, p. 321. Among the points here mentioned are the following:—Very short skip distance effects; in recent tests, reflection at practically normal incidence has been observed on waves down to 30 m. At 11.27 km. distance, all waves from 60 to 30 m. showed marked vertical reflection, which appeared to be less on the longer waves than on the shorter. "These results are interesting in connection with the very long (Stôrmer) echoes." Elimination of fading; the use of two slightly different frequencies; "recent tests seem to indicate that there is a big gain in using modulated waves instead of pure C.W., with a much higher speed of working"; use of two aerials spaced many wavelengths apart; use of combination of signals from a horizontal and a vertical aerial. Different types of fading:—at the edge of the skip distance the more bent (and incidentally less attenuated) of the two rays, circularly polarised by the earth's field, is alone received; at slightly greater distances both rays combine and produce marked inverse or "polarisation" fading; at great distances the horizontal ray diminishes in importance and the fading is mainly of the "interference" type. Magnetic storm fading is dealt with, and the considerable increase of "whistlers" (January Abstracts, p. 38) during such storms is referred to. The concluding section discusses theory, more particularly the rôle of the Heaviside layer; the conception of this as a complex structure of scattering clouds necessitates revision of the usual ray theory. If the scattering in the lower levels of the layer is particularly intense, the emergent ray may be very highly diffused and the emergent energy may entirely lose its ray formation.

TRANSOZEANISCHE DRAHTLOSE TELEGRAPHIE MIT KURZEN WELLEN (Transoceanic Wireless Telegraphy on Short Waves).—H. Rukop. (*Verhandlungen der Ges. deut. Naturforsch.* 90 Versamm.)

The complete paper, an abstract of which was referred to in March Abstracts, p. 145.

ACTIVITÉ SOLAIRE ET PROPAGATION (Solar Activity and Propagation).—R. Mesny. (*L'Onde Élec.*, March, 1929, V. 8, pp. 103–110.)

A survey of the work done on this subject by Espenschied, Anderson and Bailey, Pickard, Maurain, and Austin (see earlier Abstracts).

THE SCATTERING OF LIGHT BY ELECTRONS.—G. Glockler. (*Phys. Review*, No. 1, 1929, V. 33, p. 116.)

As an example of the writer's conclusions, an encounter with an electron with 1,000 v. velocity would shift the green Hg-line 5461 by 685 A.U.

REFRACTION OF LIGHT WAVES BY ELECTRONS.—S. K. Mitra and H. Rakshit. (*Nature*, 25th May, 1929, V. 123, p. 797.)

Assuming that long-distance reception of wireless waves is due to refraction by electrons in the Heaviside layer, the writers use Larmor's velocity formula to deduce that for a wavelength of 10^5cm., an electron density N of 0.3 per c.c. is enough to produce the observed bending round the earth. In the case of light waves, λ is of the order of 10^{-5}cm., leading to a large value of N in order that light rays may bend round the earth, and a still larger value if the bending is to be observed in the laboratory. After mentioning that the writers have—so far unsuccessfully—tried to detect such bending, the letter describes the reasoning (from Langmuir's formula for the density of space charge at the surface of a hot plane surface) which leads them to believe that such bending could be produced and detected in the laboratory. A thoriated tungsten strip, say 10 cm. long, would be used to form the electron atmosphere; since at a distance of only 0.1 mm., the electron density falls to one ten-thousandth of its value at the surface, it would probably be advantageous to pull the electron cloud upwards by a positively charged plate held a few millimetres above the surface.

THE EFFECT OF STRONG ELECTRIC AND MAGNETIC FIELDS ON THE RECTILINEAR PROPAGATION OF GAMMA RAYS.—J. H. J. Poole and A. J. Clarke. (*Roy. Dublin Soc.*, 26th March, 1929; short summary in *Nature*, 25th May.)

Testing J. J. Thomson's suggestion that just as electrons show some of the characteristics of very high frequency wave trains, so very hard gamma rays might possess some of the properties of charged particles (*cf.* February Abstracts, pp. 113–114), the writers have been unable to detect any deflection of such rays either by electric or magnetic fields.

OZONE ABSORPTION DURING LONG ARCTIC NIGHT.—G. M. B. Dobson. (*Nature*, 11th May, 1929, V. 123, p. 712.)

Referring to Wood's supposition that an extension of the ultra-violet spectra of sun or stars could be obtained near the pole at the end of winter, on the assumption that the atmospheric ozone is formed by ultra-violet solar radiation and should therefore be of low value at that time and place, the writer states that regular and consistent results show that the lowest ozone values at any time of year are in the tropics, the highest being in high latitudes in spring (when it is about twice the autumn value). The solar ultra-violet radiation tends to reduce rather than to increase the amount of ozone, since there is far more energy in the longer waves (which decompose ozone) than in the shorter ones (which form it). What does form the ozone is not, at present, certain; but the connection found between the amount of ozone and magnetic disturbance might suggest some action associated with the aurora, though occurring lower down. See also April Abstracts, pp. 202–203.

THE ABSORPTION OF ULTRA-VIOLET LIGHT IN OZONE.—A. Läuchli. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 321.)

Measurements of the absorption coefficient over the range 238–334 $\mu\mu$, using a differential ozone meter.

FORMATION OF OZONE BY KATHODE RAYS.—A. L. Marshall. (*Journ. Am. Chem. Soc.*, December, 1928, V. 50, pp. 3178–3197.)

Ozone is both formed and decomposed under the influence of these rays, and with continued raying a steady state is reached (independent of the current) with an ozone concentration of 1 mol. to 1,700 of oxygen, as compared with 1 to 12 with the silent electric discharge. The cathode-ray tube by which these tests were made is described. It can be loaded up to 200 kw., with a current of 0.001 A.

THE TRANSFER OF HEAT BY RADIATION AND TURBULENCE IN THE LOWER ATMOSPHERE.—D. Brunt. (*Proc. Roy. Soc.*, 2nd May, 1929, V. 124 A, pp. 201–218.)

Author's summary:—A simplifying assumption as to the nature and extent of the effects of radiation and absorption by water-vapour in the atmosphere, based on Hettner's measurements of absorption by water-vapour, makes it possible to reduce the problem of the transfer of heat by radiation and absorption to a tractable form. This transfer is found to be analogous to the conducting of heat in a solid, the ordinary coefficient of molecular conductivity being replaced by a much larger coefficient, the radiative diffusivity K_R.

The transfer of heat by eddies in a turbulent atmosphere is evaluated for a compressible atmosphere, and it is shown that the eddy flux of heat is proportional to the difference between the lapse rate and the adiabatic, and to the eddy-diffusivity K, defined by Taylor.

The relative magnitudes of K_R and K are considered. K is normally of the order of 10^3 in inversions but is usually greater than 10^5 when the atmosphere is fairly turbulent. Both radiation and turbulence tend to smooth out any bends in a temperature height curve.

MESSUNGEN DES BRECHUNGSEXPONENTEN VON WASSER ZWISCHEN 23 UND 73 CM. WELLENLÄNGE (Measurements of the Index of Refraction of Water between 23 and 73 cm. Wavelength).—E. Frankenberger. (*Ann. der Phys.*, 19th April, 1929, Series 5, V. 1, No. 7, pp. 948–962.)

The index for pure water was found to be quite constant throughout the wave-range; apparently also down to 10 cm. Contrary to previous results, weak salt and colloidal solutions showed no dis-

persion, for a wave-range 50–60 cm. (*See also* Martey and Jones, Abstracts 1928, V. 5, p. 522.)

MAGNETIC SUSCEPTIBILITY OF OZONE.—V. I. Vaidyanathan. (*Indian Journ. Phys.*, 30th November, 1928, V. 3, pp. 151–163.)

Tests leading to the conclusion that ozone is diamagnetic.

AN ANALYSIS OF THE CHANGES OF TEMPERATURE WITH HEIGHT IN THE STRATOSPHERE OVER THE BRITISH ISLES.—L. H. G. Dines. (*Roy. Met. Soc.*, summarised in *Nature*, 4th May, 1929, V. 123, p. 700.)

THE PROPAGATION OF SOUND IN GASES.—D. G. Bourgin. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 821–841.)

The first part develops the ideas and equations for a theory which takes account of the collision excitation and de-excitation of the molecules composing the gas. In brief, it is assumed that under the influence of collisions of the first kind some molecules are thrown into states of higher energy from which they may return to lower energy levels either spontaneously or as the outcome of collisions of the second kind. The second part advances a theory of sound propagation in a mixture of two gases—the first attempt, the author believes, to deal with this problem.

T.S.F. ET MÉTÉOROLOGIE (Wireless and Meteorology).—De la Forge. (*QST Franç.*, March, 1929, V. 10, pp. 8–12.)

An article on Fuch's paper dealt with in January Abstracts, p. 40.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

SOLAR STREAMS OF CORPUSCLES AND MAGNETIC STORMS.—S. Chapman. (*Nature*, 25th May, 1929, V. 123, p. 811.)

A short summary of the paper in *Monthly Not., R. Astron. Soc.*, for March. The writer uses Milne's result that the Doppler effect will enable upward moving atoms to climb out of the absorption lines associated with them, and to be accelerated away from the sun; the acceleration diminishes as the distance increases, and for the greater part of the journey to the earth's orbit the motion is nearly uniform; the time—between one and two days—agreeing with the lag often observed after the passage of a spot over the central meridian of the sun before the arrival of the storm. While individual atoms are moving nearly radially, the stream as a whole is rotating with the sun and so overtakes the earth; magnetic storms therefore begin near the sunset meridian of the earth. It is estimated that the breadth of a stream when crossing the earth's orbit is of the order of 50 earth-radii, so that it would take 25 minutes to sweep over the earth. Discussing the difficulty of explaining how the corpuscles can penetrate deeply enough into the atmosphere to give rise to low-level auroræ, it is suggested that the extrapolation used to estimate the resistance of air at extremely low density may be at fault.

ON LIGHTNING: THE KELVIN LECTURE.—G. C. Simpson. (*Engineer*, 3rd May, 1929, V. 147, pp. 483–484.)

Summary of the lecture before the I.E.E. Cathode ray oscillograms have now proved that the main discharge of a lightning flash consists of a unidirectional current starting at zero, rising to a maximum and then decreasing more or less rapidly to zero. Clouds are practically perfect non-conductors, and—having no capacity—cannot act in the Leyden jar manner. But the channel of the flash, once formed, has capacity and self-induction, and if its resistance is not too great it will oscillate like an aerial. Thus the combined effect is somewhat similar to that of a singing arc. The quantity of electricity in an average flash varies between 10 and 50 coulombs. The potential reached in a cloud before the passage of a 20-coulomb flash is in the neighbourhood of 1,000 million volts; the energy in such a flash is about 10^{17} ergs; the average duration is greater than one-thousandth of a second. The mean current is of the order of 20,000 A., but instantaneous values are far greater and seem sometimes to approach 100,000 A. A copper conductor having a cross section of 0.08 sq. inch can safely carry the most violent discharge likely to occur, but a local resistance (*e.g.*, a bad earth) of 10 ohms may raise the potential of the conductor to a million volts. The writer believes that practically all troublesome surges in lines are due to direct strokes, *not* to induction.

THE PAST COLD WINTER AND THE POSSIBILITY OF LONG-RANGE WEATHER FORECASTING.—W. J. Pettersson. (*Nature*, 25th May, 1929, V. 123, pp. 796.)

The writer considers that at present all attempts to forecast the weather more than a week ahead are not more than 50 per cent. successful, owing to the neglect of direct terrestrial influences such as that of the physical state of the surface waters of the oceans, and to the insufficient attention given to Bjerknes' "polar front" theory. He quotes Witting's Baltic observations of 1927 and gives reasons for thinking that the very large cold layer at 10 fathoms found there may well account for the cold winter of 1928. He suggests that international co-operation in the systematic study, at least once but preferably twice a year, of the physical states of the Baltic and other seas and oceans in and around Europe, followed by a quick publication of results, would sometimes save millions of pounds by the prediction—in good time—of winters such as that of 1928–1929.

MAGNETIC STORMS AND SOLAR ACTIVITY, 1874 TO 1927.—W. M. H. Greaves and H. W. Newton. (*Monthly Not., Roy. Astron. Soc.*, 89, November, 1928, pp. 84–92.)

Supplementary to the paper referred to in Abstracts, 1928, V. 5, p. 579.

RADIAL LIMITATION OF THE SUN'S MAGNETIC FIELD: SUN'S GENERAL MAGNETIC FIELD AND THE CHROMOSPHERE.—S. Chapman. (*Monthly Not., Roy. Astron. Soc.*, 89, November, 1928, pp. 57–79 and 80–84.)

PROPERTIES OF CIRCUITS.

OUTPUT CHARACTERISTICS OF THERMIONIC AMPLIFIERS.—B. C. Brain. (*E.W. & W.E.*, March, 1929, V. 6, pp. 119–127.)

"All the data required to fix the operating conditions of a valve for maximum undistorted output can be obtained (by the aid of a slide-rule and five minutes work) from a knowledge of two valve constants. These constants are embodied in the information which usually accompanies commercially made valves." They are the amplification factor *m*, and the constant *k* which can be calculated from any set of simultaneous values of V_a, I_a and E_g. The writer deals first with the generally accepted rule that for best power output the coupled load resistance should be twice the value of the A.C. resistance of the output valve, and shows that this valve-resistance should be taken for peak-value of anode current and *not*, as is common practice, at the working bias (the latter method leading to serious error when applied to pentodes). He then deduces that for triodes the ideal load resistance should be about 1.6 times the A.C. resistance of the valve at the working bias. But if the mean anode current with this optimum load resistance exceeds the makers' limitation (as frequently happens) the load resistance may have to be much greater than the optimum value. After showing how to allow for this, and for voltage drop along filament and the use of A.C. for filaments, he enumerates three points emerging from his investigation :—the maximum output from a valve is proportional to the 2.5 power of the anode voltage and to the constant *k*; the output of valves of identical construction but with differing *m* values operating with the same anode voltage is inversely proportional to the 1.5 power of *m*; the grid bias for maximum output is directly proportional to the anode voltage and inversely proportional to *m*.

SUR LES TRANSFORMATEURS INTERMÉDIAIRES ET LA REPRODUCTION SANS DISTORSION (Intermediate Transformers and Distortionless Reproduction). — I. Podliasky. (*L'Onde Élec.*, March, 1929, V. 8, pp. 111–118.)

Referring to Jouaust's paper and to Turner's letter on the English practice of using low resistance valves and reducing the leakage flux of the transformer, to avoid trouble with the "parallel resonance" (January and May Abstracts, pp. 41 and 268), the writer offers some remarks which support Turner and which may assist in the precalculation of "aperiodic" transformers; these have been confirmed by tests on English types of distortionless ("uniform spectrum") transformers. Curves of the Marconi "Ideal," Ferranti, and G.I.K. transformers are given, showing the absolute flatness at the region of parallel resonance, a gradual rise towards the upper end of the musical spectrum and a resonant point (leakage resonance) at the limit of this spectrum. The writer's mathematical investigation of the conditions for parallel and series resonance is applied, as an example, to the calculation of such a transformer.

The often-raised question of "phase reproduction" is then discussed briefly; it is concluded that the ordinary reproduction curve (taken by applying an A.C. voltage of constant amplitude and variable frequency to the grid and measuring the voltage at the ends of the transformer secondary by an instrument representing about the impedance of the input circuit of the next valve) justifies its name, in that it completely represents the reproduction of complex sounds.

ÜBER DIE HÖCHSTLEISTUNGEN UND VERZERRUNGEN BEI ENDVERSTÄRKERN (On Maximum Output, and Distortion, in Power Amplifiers).—H. Bartels. (*E.N.T.*, January, 1929, V. 6, pp. 9–17.)

It is shown that the maximum obtainable A.C. output, as a function of anode load of the valve, is *not* (as has hitherto been assumed) reached at the anode voltage corresponding to the condition $R_a = 2 R_i$,* but continually increases with the anode voltage up to a value twice as great as at that point. At the same time, the distortion due to the curvature of the valve characteristic decreases. More important still, the increase of anode voltage is accompanied by an increasing breadth of transmitted frequency band: a 50 per cent. increase of voltage doubles the frequency band. *See also* Hanna and collaborators, Abstracts, 1928, V. 5, p. 344.

OPTIMALE INDUKTIVITÄT VON SCHWACHSTROMTRANSFORMATOREN (Optimum Inductance of "Small Current" Transformers).—G. Pfeifer. (*E.N.T.*, April, 1929, V. 6, pp. 157–161.)

In commercial telephony, where the undistorted transmission of only three octaves is quite enough, the question of a linear frequency characteristic presents no difficulty and a transformer can therefore be designed with an eye to maximum efficiency. The writer deals first with a 1 : 1 transformer, obtaining an equation from which he derives curves showing the best ratio L/R for various frequencies (of which the 5,000 p.p.s. is the most important for speech) at any particular value of r/L. Here L is the inductance of each winding, r its resistance; R is the resistance of the generator or of the receiver (since a 1 : 1 transformer is being considered, these are assumed equal); the ratio r/L for modern transformers varies from 10 to 60. He then shows how to apply his results to transformers of ratio other than unity.

EFFECT OF ANODE-GRID CAPACITY IN ANODE-BEND RECTIFIERS.—E. A. Biedermann. (*E.W. & W.E.*, March, 1929, V. 6, pp. 135–139.)

Conclusion of the paper referred to in April Abstracts.

ÉTUDE D'UN SYSTÈME OSCILLANT : SUPERRÉACTION (Study of an Oscillating System : Super-regeneration). — T. Konteschweller. (*QST Franç.*, March and April, 1929, V. 10, pp. 13–17 and 33–34.)

A mathematical analysis : to be continued.

* With transformer coupling: R_i being the internal resistance of the last valve.

OSCILLAZIONI PROPRIE DEL TRIODO IN ACCOPPIAMENTO MAGNETICO (Natural Oscillations of a Triode with Magnetic Coupling).—R. Malagoli. (*N. Cimento*, July, 1928, V. 5, pp. 239–255.)

The author deals first with the internal resistance of a valve with control grid, and the dependence of this resistance on the values in the associated circuits. He then investigates the electrostatic relation between grid and anode, and the formation of oscillations between these electrodes, giving an expression for the pulsations of grid-current as a function of the circuit constants and the grid/anode capacity. Under certain conditions these oscillations are of such low frequency that they can be heard in a telephone receiver directly connected.

NON-REACTIVE COUPLING.—(German Pat. 452814, Banneitz.)

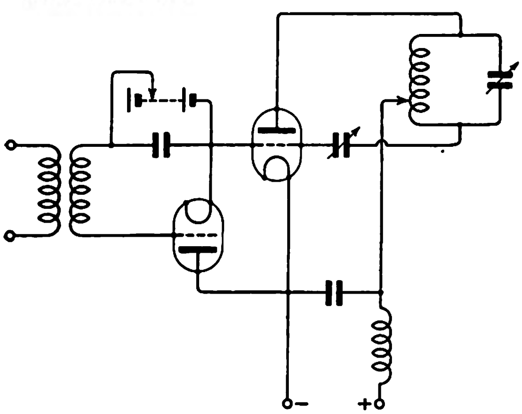
Parallel to the coupling inductance, which forms part of the secondary circuit inductance, is connected a capacity which forms—with the coupling inductance—a circuit so out-of-tune with the working frequency that reaction on the primary circuit is reduced to a minimum.

DAMPING AND OSCILLATION: EXCITATION OF APERIODIC SYSTEMS.—F. Tank and K. Graf. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 369.)

Circuits containing only resistance and inductance, or resistance and capacity, when suitably connected and coupled together through any type of amplifier, can be made to generate oscillations. The paper considers the cases of various forms of amplifier.

HOCHFREQUENZSTEUERUNG MIT GITTERGLEICHSTROM (H.F. Control by Grid Direct Current). K. Krüger and H. Plendl. (*Naturwiss.*, 15th March, 1929, V. 17, pp. 180–181.)

In the grid-lead of a reaction-coupled transmitter valve a resistance, selective for H.F., is



connected—in the form of a control triode as in the diagram.

Externally this arrangement resembles an ordinary grid-controlled telephone transmitter, but its action is described as fundamentally different. The control valve is so biased as to present a very high resistance to the grid current of the main valve, so that it blocks the oscillation of this. If a H.F. voltage is applied to the grid of the control valve, this blockage is removed for that particular frequency, and the main valve can oscillate to it or to one of its harmonics. Thus a large power can be controlled, without intermediate steps, by a small power such as is given by a quartz-oscillator. For reception, also, very high amplification or a relay action can be obtained.

TRANSMISSION.

ZUM PROBLEM DER ERZEUGUNG KURZER ELEKTRISCHER WELLEN DURCH BREMSFELDER (On the Problem of the Production of Short Electric Waves through "Brake-fields").—H. E. Hollmann. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 128–132.)

Author's summary:—For more exact examination of the short-wave oscillations (13–18 cm. wave region) found by Pierret and by Hollmann, using a French short-wave valve Type Métal TMC, electrode systems were used by which the number of grid turns could be varied in addition to changes in tuning and working conditions. No oscillations were found corresponding to Pierret's theory, in which—contrary to the B-K ideas—the frequency depends also on the spacing of the grid wires. But oscillations in the grid system were obtained of double the frequency of the B-K zone, down to a wavelength of 13 cm. The intensive oscillations at 17–18 cm. were traced to an oscillating circuit built up of the grid spiral and its supports.

GENERATION OF SHORT ELECTRIC WAVES BY THE METHOD OF BARKHAUSEN AND KURZ.—F. Tank and E. Schiltknecht. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 368.)

An experimental investigation was made of the B-K method and the results are used as a basis for a theory. "The oscillation phenomena depend on a control effect of the oscillating space charges on the space-charge density of the emission current, which latter must, therefore, have reached its saturation value. The effect of the external circuit, coupling effects, harmonic oscillations and the behaviour in a magnetic field are also dealt with."

VACUUM TUBES AS OSCILLATION GENERATORS.—D. C. Prince and F. B. Vogdes. (*Gen. Elec. Review*, May, 1929, V. 32, pp. 288–294.)

This final part of the series concludes the treatment of a high-frequency circuit with square current waves, referred to in May Abstracts, p. 269.

MODULATING SYSTEM FOR SEPARATELY EXCITED TELEPHONE TRANSMITTING SET. (German Pat. 470322, Schäffer, pub. 18th January, 1929.)

A system of modulation designed to avoid the danger of secondary emission, which is liable to occur—particularly in water-cooled oscillators—if the D.C. path to the grid is given a high resistance

during the grid-current modulation. A diagram of this arrangement is given in *Zeitschr. f. Hochf. Tech.*, April, 1929, p. 151.

GENERATION OF SHORT WAVES. (German Pat. 453289, Esau.)

Spark dischargers are fed with A.C. of high frequency above the audible zone, so that the successive trains of damped waves form a practically undamped wave-train.

SIGNALLING BY FREQUENCY MODULATION.—N. E. Holmblad. (*E.W. & W.E.*, May, 1929, V. 6, pp. 260–261.)

Referring to the Westinghouse patent abstracted on p. 170 of the March issue, and in particular to the claim that the width of the side-bands is reduced to a few hundred cycles only, the writer analyses the process and comes to the conclusion that for small values of *k* (modulation constant) it gives the same width of side-band as the ordinary amplitude-modulation, while for large values of *k* much broader side-bands are introduced.

RECEPTION.

LA QUALITÉ DE LA RÉCEPTION RADIOPHONIQUE (Quality of Radiotelephonic Reception).—P. David. (*L'Onde Élec.*, March, 1929, V. 8, pp. 119–129.)

Completion of the paper referred to in June Abstracts, p. 328. After detection the current has to be amplified by one or more L.F. stages: the coupling, by resistance or transformer, has to fulfil certain conditions in order to avoid distortion. General conditions for a transformer are given as: transformation ratio not too high (2.5 to 3 as a maximum for ordinary French valves): inductance sufficiently large to assure reproduction of low frequencies—" plenty of wire and plenty of iron ": distributed capacity and core losses sufficiently slight to assure reproduction of high frequencies. These conditions seem rather contradictory, but curves of a transformer designed by Decaux, and of another (special for television) made by the Bell Telephone Company, show that transformer coupling is by no means incompatible with quality. The first curve shows no appreciable weakening until below 100 frequency: the second " realises perfection." With resistance coupling non-uniform distortion is more easily avoided, but even here care must be taken: *e.g.*, the shunt path formed by the valve capacity must be negligible compared with its ordinary conductance; this imposes a maximum on the internal resistance of the order of 200,000 ohms; recent special valves with resistances round a megohm are by no means satisfactory for fidelity. On the other hand, for the bass frequencies the coupling capacities must be large enough: 10 mμF. is not too great.

Distortion depending on the characteristic curves of the valves is then considered. For transformer coupling, grid current changes would produce distortion if they were not prevented by suitable bias. With resistance coupling there is no distortion due to the grid, but plate distortion is more difficult to avoid, since the grid mean voltage is not fixed and distortion, due to the characteristic-bend, is liable to arise. Non-linear distortion due to the iron cores of a transformer-coupling is referred to briefly, together with its cure. On the whole, the author is inclined to prefer the transformer-coupling, chiefly on account of its greater stage amplification. Loud-speakers are treated in a short section, the next section dealing with the possibility of correcting the total distortion by opposing the various partial distortions. In the final section the author quotes the dicta of various workers as to the strength of signals necessary for good reception. Espenschied's ideas (10–50 mv./m.), lead to a range of 25 and 50 km. for a 5 and 10 kw. transmitter respectively; Goldsmith is less exigent, with 45 and 160 km. for 5 and 50 kw.; Edwards and Brown gave 18 and 45 km. for 1 and 10 kw., or about double these ranges for open country. These values refer to 200–600 m. waves; they could be increased slightly for " long " waves (1,500 m.). Actual French practice considers as " normal " ranges 5 to 10 times as great as these. The writer considers the truth to be somewhere between the American and French ideas.

In the discussion Raven-Hart asks: (1) If it is not possible to improve quality without losing selectivity (and without having to use a band-pass filter) by employing two or more tightly coupled circuits tuned to neighbouring but not identical frequencies. (David refutes this: the plan rounds off the top of the curve but diminishes the slope of the sides. To work well, complex arrangements would be necessary to give, in addition to resonance with the wanted band, a counter-resonance with systematic stifling of the interfering waves—which would appear to him to come under the title of filters). (2) Why Beatty's " demodulation effect " had not been taken into account (David condemns this article as founded on an " insufficiently precise geometrical analysis " and as neglecting the effect of reaction on the damping). (3) Would not anode detection, being less sensitive to weak signals, reduce the necessary selectivity by suppressing such weak interfering signals as were let through by the tuning circuits? (Anode detection may be just as bad as grid, from this point of view: it all depends on the input amplitude at the detector). (4) Is it not best to reduce the upper frequencies, in view of the subjective greater loudness of these as heard by the ear? (This plan raises special difficulties, but the question is worthy of investigation). Finally, Borias suggests adjusting the carrier frequency to one extremity of the band passed by the tuning circuits, instead of to its middle; only one modulation band would be received, the amplitude would be halved, but the frequency-range doubled. Moreover, if the side-band furthest away from the interfering station were chosen, the interference would be reduced. Also the beats between the two side-bands would be avoided. (David replies that the remark is very interesting, that no doubt the plan is adopted unknowingly by many listeners, and that this is one reason for the discrepancy between working and theoretical ranges; but he considers that in view of the loss in amplitude and of the fact that the actual shape of the resonance curves prevents the full advantage described by Borias from being obtained, the gain obtained does not really affect his conclusions).

SELEKTIVITÄT UND FERNEMPFANG (Selectivity and Distant Reception).—M. v. Ardenne. (*Rad. f. Alle*, May, 1929, pp. 193–201.)

Observations on signals from the European broadcasting stations (*cf.* March Abstracts, p. 161) are here plotted so as to show the effects on selectivity of various values of effective damping (from 0.08 to 0.005), and of a directively efficient frame aerial.

NOTE ON THE PROBLEM OF SELECTIVITY WITHOUT REDUCING THE INTENSITY OF THE SIDE-BANDS.—W. B. Lewis. (*E.W. & W.E.*, March, 1929, V. 6, pp. 133–134.)

A receiver with an aperiodic R.F. amplifier is receiving strong but unwanted telephony and weak wanted telephony on a neighbouring wavelength. An oscillator is coupled up and tuned exactly to the weak carrier wave, the R.F. current supplied being made several times greater than that of the unwanted signals. After detection the envelope of the R.F. current is the combination of beats (*a*) of infinite period with the wanted carrier; (*b*) of supersonic frequency with the unwanted carrier and sidebands, and (*c*) of audio-frequency with the wanted sidebands: the result being that only the wanted telephony is heard, with no diminution of the higher frequencies if the amplifier is correctly designed. In preliminary experiments, anode-bend detection was abandoned as signals were only wiped out if the supplied oscillations overloaded the valve; with a crystal detector the arrangement worked in the manner expected, but a rushing noise was heard which appeared to originate in the detector: this was not serious for loud signals. Quality was good with these, but faint signals were "horribly distorted"—partly, if not wholly, owing to relative wobbling of carrier and oscillator frequencies.

KURZE UND LANGE WELLEN DER DRAHTLOSEN TELEGRAPHIE (Short and Long Waves in Wireless Telegraphy).—F. Kiebitz. (*Naturwiss.*, 29th March, 1929, V. 17, pp. 205–208.)

A survey of the relative behaviour of short and long waves so far as radiation and reception is concerned, but not as regards propagation. A point mentioned relating to the strength of signal necessary for reception is that theoretically at least one electron is necessary for each period, in order that the current may still be sinusoidal after amplification to the 10th power or so; for a 475 m. wavelength this implies a current of 10^{-13} A. This is for telegraphy, where a current has to be merely either present or not present; for telephony it must be variable in amplitude in the ratio of at least 100 to 1, so that the minimum current becomes about 10^{-11} A. if, in spite of its atomic structure, it is to reproduce speech.

THE THEORY OF PUSH-PULL: PART III.—N.W. McLachlan. (*Wireless World*, 15th May, 1929, V. 24, pp. 505–509.)

Final part of the article in the issues of 13th June, 1928, and 30th January, 1929. "New method of treating the output circuit. The causes and prevention of parasitic oscillations." The new method of treating the output involves the use of two separate transformers and two separate loud speaker coils, coupled mechanically but with a minimum of electromagnetic coupling.

AERIALS AND AERIAL SYSTEMS.

UNTERSUCHUNG DER BRAUCHBARKEIT VON RAHMENANTENNEN FÜR SENDEZWECKE (Investigation of the Utility of Frame Aerials for Transmitting Purposes). — W. Nestel. (*Zeitschr. f. tech. Phys.*, No. 4, 1928, V. 9, pp. 143–145.)

The radiation efficiency (ratio of applied H.F. input to radiated output) increases with decreasing wavelength and can reach the same order of magnitude as that of a vertical aerial: the frame aerial has, moreover, several advantages for short-wave transmission, *e.g.*, simplicity of electrical connection, and ease of wavelength adjustment.

TUBE FRAME AERIAL. (German Pat. 453291, Geles.)

An insulated wire runs axially up a vertical conducting tube. At one end, tube and wire are connected directly or through an air condenser: at the other, they are connected through one winding of a H.F. coupling transformer.

FRENCH SYSTEM OF DIRECTIONAL AERIALS FOR TRANSMISSION ON SHORT WAVES.—H. Chireix. (*E.W. & W.E.*, May, 1929, V. 6, pp. 235–244.)

VALVES AND THERMIONICS.

BADANIE PRZEBIEGÓW ELEKTROSTATYCZNYCH W LAMPIE KATODOWEJ NA MODELU (The Investigation of Electrostatic Phenomena in Valves by Means of Models).—J. Groszkowski. (*Wiadómosci i P. Inst. Radjotec.*, Warsaw, 15th March, 1929, V. 1, 21 pp.)

Author's summary: "First the author examines the question of investigation with the aid of models, and the possibility of applying such methods to electronic valves. He then considers the law of similarity between model and subject, as regards inter-electrode capacity and amplification coefficient. The ideas of "local" and "linear" amplification coefficients are introduced: these are discussed as regards the effect on them of the grid and of the edges of the electrode system." The author then describes his method of exploring the electrostatic distribution, taking as an example his model of a French triode Type "R," on a 33 : 1 scale. An alternating potential is supplied to the "plate" and "grid" of this model, the "filament" going to the slider of a potentiometer across the source of A.C. Between the "filament" and the "grid," an exploring electrode can be moved about: this is connected to the grid of a real valve; telephones in the plate circuit of this serve as the indicator, an adjustment being made (for each position of the exploring electrode) by varying the position of the slider of a second potentiometer across the source of A.C.; this slider being connected to the filament of the real valve. The results are given of the measurements of the local amplification coefficient

at different points of the space between cathode and grid ("influence of grid mesh and edges"), as well as the distribution of electrostatic field in this space.

THE E.M.F. OF THERMAL AGITATION.—E. K. Sandeman and L. H. Bedford.—*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 774–782.)

Confirmatory evidence has been obtained on Johnson's results (Abstracts, 1928, V. 5, p. 581) and a simple precision formula has been derived for calculating the magnitude of noise disturbance which occurs on the grid of the first stage of any amplifier. This formula is admittedly only applicable under certain conditions (uniform amplification of a given band of frequencies; impedance between grid and filament of first valve a pure resistance shunted by a capacity, within the pass-band of the system) but these conditions usually occur in practice. The formula is

$$N = \frac{JT^{\frac{1}{2}}}{\sqrt{2\pi C}}\sqrt{\tan^{-1} 2\pi RCF_2 - \tan^{-1} 2\pi RCF_1}$$

(the inverse tangents being expressed in radians) where $J = 7.4 \times 10^{-6}$, $T =$ absolute temperature (normally about 293), $R =$ total grid-filament resistance in ohms, $C =$ total g.-f. capacity in farads, F_1 and $F_2 =$ the frequency limits of the pass range of the receiving system in cycles per second.

SUR LA CARACTÉRISTIQUE DE LA LAMPE À TROIS ÉLECTRODES (The Characteristic of the Three-Electrode Valve).—Ch. Jeanjaquet. (*Helvetica Phys. Acta*, No. 7/8, 1928, V. 1, pp. 468–470.)

The space-charge characteristic of an amplifier valve is a $V^{3/2}$-curve only in the ideal case of a very long uniformly hot cathode, *i.e.*, neglecting the end-effects. The paper gives a formula which allows for the cooling effect of the filament leads and which agrees with an experimental curve.

ELECTRON REFLECTION FROM COBALT, AND ELECTRON WAVES.—M. N. Davis. (*Nature*, 4th May, 1929, V. 123, pp. 680–681.)

"Measurements by a number of observers of the velocity distribution of the electrons leaving the surface of a metal under bombardment by a beam of electrons of known velocity have shown that a part of the secondary electrons have the primary velocity, the rest having, in general, a lower velocity. No attempt appears to have been made to resolve the secondary emission into its two components when the secondary emission is studied as a function of the velocity of the primary electrons. This is a preliminary account of the results of such an experiment" [on cobalt].

EXPERIMENTELLES ÜBER DEN ELEKTRONENAUSTRITT AUS METALLEN (Experimental Results on Electron Emission from Metals).—F. Rother and E. Münder. (*Physik. Zeitschr.*, 1st February, 1929, pp. 65–68.)

The writers obtain results contradicting those of Millikan and Eyring with the same arrangement (cylinder and stretched axial wire).

ON ELECTRONS THAT ARE "PULLED OUT" FROM METALS.—E. H. Hall. (*Proc. Nat. Acad. Sci.*, March, 1929, V. 15, pp. 241–251.)

THERMIONIC CURRENT IN DENSE GASES WITH CYLINDRICAL ELECTRODES.—H. König. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 362.)

HYSTERETIC EFFECTS IN THE POSITIVE EMISSION FROM HOT BODIES.—H. P. Walmsley. (Summary in *Science Abstracts*, Sec. A, 25th April, 1929, V. 32, p. 361.)

SHOT EFFECT IN THERMIONIC EMISSION FROM OXIDE-COATED ELECTRODES.—N. H. Williams and W. S. Huxford. (*Phys. Review*, No. 1, 1929, V. 33, p. 118.)

From measurements of the shot effect conclusions can be drawn as to the charges on the positive thermions. From a special barium-oxide-coated hot cathode, both positive and negative ions were emitted; measurements of the ion charges gave the same value as for the electron charges.

DIE ELEKTRONEN- UND IONENSTRÖME IN GASEN BEI NIEDRIGEN DRUCKEN (Electronic and Ionic Currents in Gases at Low Pressures). —G. Spiwak. (*Zeitschr. f. Phys.*, 7th March, 1929, V. 53, No. 11/12, pp. 805–839.)

CONDENSER AS VALVE HEATING ELEMENT.— (Brit. Patent 307325, Graham Amplion and P. Freedman, acc. 5th March, 1929.)

The condenser is raised to the required temperature by means of its dielectric losses.

LES CATHODES À OXYDES: PROPRIÉTÉS, PRÉPARATION (Oxide-coated Cathodes: Properties and Preparation). —— Boussard. (*Bull. d. l. Soc. Franç. d. Phys.*, 15th Feb., 1929, p. 405.)

This paper includes a table according to which the following are the comparative values of the total emission in milliamperes for each watt spent in heating:—pure tungsten 5, thoriated tungsten 30–40, oxide-coated by old methods 30–40, by new methods 100–150. The corresponding slopes of characteristic (mA./v.) are given as 0.1, 0.2, 0.2 and 0.6.

ÜBER DIE SCHWANKUNGEN DER TEMPERATUR LÄNGS EINEM GEGLÜHTEN DÜNNEN WOLFRAMDRAHT (The Temperature Fluctuations along a Thin Annealed Tungsten Wire).— A. Denissoff. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 168–171.)

The author quotes (as an example of the importance of the investigation of the differing local temperatures caused by minute differences of cross section) Becker's statement that the life of a tungsten filament is inversely proportional to the 39th power of the absolute temperature. The method described is a photographic one.

THE SCREEN-GRID VACUUM TUBE.—J. E. Smith. (*Rad. Engineering*, April, 1929, V. 9, pp. 50–54.)

"A semi-technical article covering both the theory and the practical applications of the screen-grid tube, including its use as a space-charge-grid amplifier."

SOME INTERESTING FRENCH VALVES: UNORTHODOX CIRCUITS FOR MULTI-GRID VALVES. (*Wireless World*, 1st May, 1929, V. 24, pp. 465–467.)

In the French "bigrille" the inner grid is rarely used as an anti-space-charge grid, but the valve is consistently employed as the frequency changer in superheterodynes, etc. In the "Isodyne" circuit a certain amount of space charge neutralisation is, however, obtained: this is virtually a push-pull arrangement in R.F. amplification, the plate and inner grid being connected to opposite ends of the centre-tapped primary. A special form of valve is the "mixed-grid" valve, in which the two grids are of the same diameter and are interwound, so that there is no "inner" or "outer" grid. The "trigrille" is particularly useful for frequency changing: it can take over the reaction action from the plate, thus definitely separating this action from the feed to the intermediate frequency amplifier. Another three-grid type has the inner and outer grids permanently connected: these are tapped to about half the plate voltage, while the central grid is the control. Then there is a type embodying one filament, two plates, and a grid for each plate; while a valve with one filament, an inner and an outer grid, and two plates, has been used successfully not only for super-heterodyne but also for super-regeneration. Finally, a small "plateless" valve is mentioned, the anode being formed by the metallic deposit on the walls of the bulb. "Its chief characteristic is an almost complete absence of microphonic effect." A French firm's system of nomenclature is described, consisting of the letter A or B and a number. The letter indicates filament consumption (A less than one-tenth, B from one to two-tenths of an ampere) while the number gives amplification factor and mutual conductance: thus A 1404 indicates a μ of 14 and a conductance of 0.4 mA./v.

MULTIPLE VALVES. (French Patent 650441, Philips' Co., pub. 9th January, 1929.)

The one bulb contains several plate-grid systems about a common equipotential cathode, which is a tube indirectly heated (by radiation or electronic bombardment) by an internal filament. The various systems are screened from one another to prevent reaction. The combination of internal filament and tube-shaped cathode can be used for rectifying purposes.

MAKING THE A.C. HEATER TUBE NOISELESS.—A. B. Du Mont. (*Rad. Engineering*, April, 1929, V. 9, pp. 32–33.)

"A review of an investigation of hum and noise caused by various constructions of indirectly heated cathode tubes," ending with the announcement of a new De Forest valve with improved qualities as regards hum, absence of crackling noises, and quick heating.

DIE TELEFUNKEN-RUNDFUNK-RÖHREN 1928 (Telefunken Broadcast Valves, 1928).—G. Jobst. (*Rad. f. Alle*, May, 1929, pp. 208–213.)

RECHERCHES ET ESSAIS SUR LES LAMPES DE T.S.F. (Experiments and Tests on Wireless Valves).—A. Kiriloff. (*QST Franç.*, March and April, 1929, V. 10, pp. 22–29 and 51–55.)

Among the R.F. valves dealt with are the Philips' 430A and 442A, the Marconi screen-grid, and Hull types; also Robinson's two-plate valve for neutralisation. The second instalment (to be continued further) deals with L.F. valves, and refers also to the Galmard coupling-transformer arrangement ("Galmard Survolteur") in which the secondary winding is split to take the coupling condenser, and which is said to form the ideal L.F. coupling, the currents induced in that part of the secondary between condenser and grid neutralising the phase-displacement caused by the large capacity (8–10 mμF.) which is necessary to avoid distortion.

DIRECTIONAL WIRELESS.

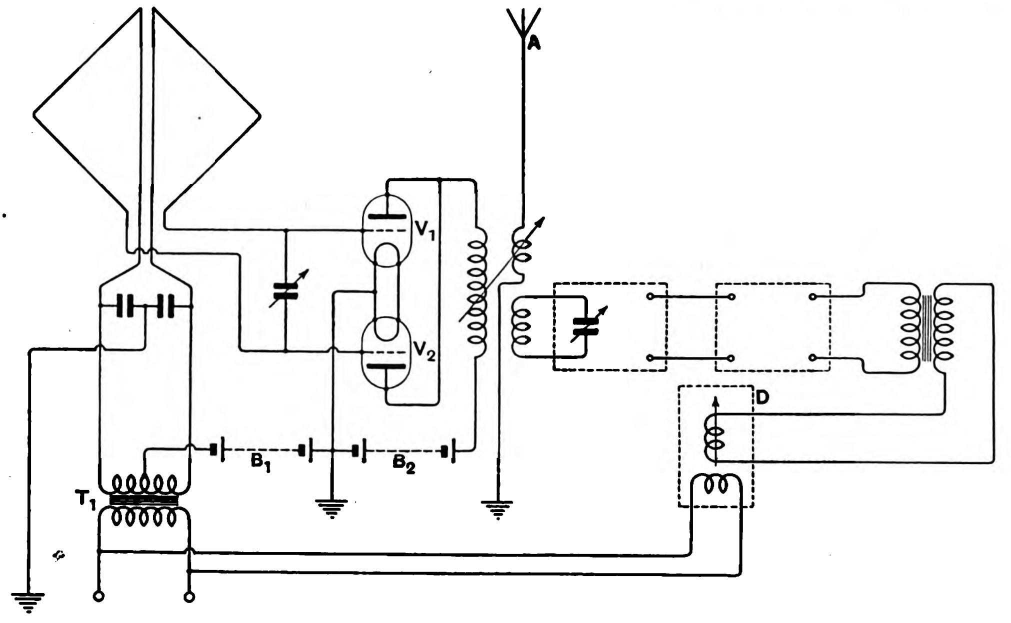
DER BORDPEILEMPFÄNGER IM FLUGZEUG (The Direction-finding Receiver for Use on Board Aircraft).—M. H. Gloeckner. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 132–138.)

This second and final part of the paper referred to in June Abstracts deals with results of various flights in which the aircraft has been navigated (a) directly towards a distant transmitter, with no allowance for drift; (b) towards one distant transmitter and away from a second; and (*c*) by compass, drift being ascertained by the D.F. and allowed for. Comparative results are indicated by diagrams.

DIREKTZEIGENDES FUNKENTELEGRAPHISCHES PEILFAHREN (Direct-reading Wireless Direction-finding Method).—R. Hell. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 138–145.)

The development of this arrangement (intended particularly for aircraft) started with Dieckmann's plan, according to which two frame aerials, at right angles to each other, are connected alternately to a receiver, the output going to a polarised current indicator. A second part of the rotating commutator, which periodically connects the aerials to the receiver, synchronously reverses the connections of the receiver-output to the current-indicator, so that the latter registers a differential effect. This scheme gives four zero-points—*i.e.*, two alternative directions at 180 deg.—and it was found also that while results were good for strong signals (0.5 kw. at 12 km.), at greater distances commutator troubles (sparking and bad contact) developed. The next step therefore was to do away with direct contacts, replacing the commutator by a condenser-system with two sets of fixed plates and one set of continuously rotating plates; this device served to connect the frames alternately to the receiver, and the periodic reversal of the galvanometer was abolished by using a dynamometer whose moving system was per-

manently connected to the receiver. The fixed coil of the dynamometer was excited from a local A.C. generator mounted on the same axle as the moving condenser plates, in such a way that the A.C. current reached its maximum when one or other of the frames was connected to the receiver. In this way the dynamometer registered the differential effect, and with this arrangement the successful range (steering direct for the transmitting station) was increased to 45 km. The next step was to cut out all mechanical rotating parts and at the same time to obtain a sense-indication which would remove the 180 deg. alternative course. As will be seen from the diagram, one split frame and one (non-directional) aerial is used, and the two valves V_1 and V_2 act as a "commutating device" which connects the frame—in a periodically reversing direction—with the aerial and with the receiver. Their grid circuits are connected so as to act in push-pull fashion both towards the R.F. currents in the frame and towards the L.F. supplied to the transformer T_1 from a local oscillator. Their grid-bias (from B_1) is so adjusted that no plate current flows in either until an A.C. voltage is provided from the transformer: each half-period of this allows plate-current to flow in V_1 or V_2, and this is reinforced by any R.F. current in the corresponding half-frame. If the frame is at right angles to the bearing-line, the moving coil of the dynamometer D only receives the steady output derived from the aerial A, and since its fixed coil is fed with L.F. alternating current it shows no deflection. It shows, however, a maximum deflection in one direction when the frame is along the bearing-line, and a maximum deflection in the other direction when the frame is turned through 180 deg. so as to be again along the bearing-line. Thus if the frame aerial is fixed athwartships, the dynamometer needle remains pointing to its central zero so long as the aircraft is heading direct for the transmitting station, moving to left or right as this direction is departed from.



Using a receiver suitable for telephony reception, the Berlin broadcasting station could be steered-to with satisfactory accuracy at 80 km.; while with a heterodyne receiver, using a frame of 1 m.^{2}, the Deutschland transmitter at Königswusterhausen gave a maximum deflection of 20 scale divisions at 500 km.

ACOUSTICS AND AUDIO-FREQUENCIES.

Coefficients of Transmission, Reflection and Absorption of Sound.—K. Satô. (*Proc. Imp. Ac., Tokyo*, November, 1928, V. 4, pp. 521–524.)

A simple experimental method is described of measuring the various coefficients for fabric-like materials. A small resonator tuned to a steady source of sound (adjustable in frequency) opens into a conical horn whose mouth is covered by the material under test. At the junction of resonator and horn, a Rayleigh disc measures the sound intensity. Among the results mentioned the transmission and absorption coefficients were found to decrease with increase of frequency for fabrics, but to increase in the case of thick and dense felt or carpet. In English.

Die Wirkung einer endlichen Schirmplatte auf die Schallstrahlung eines Dipoles.—M. J. O. Strutt. (*Zeitschr. f. tech. Phys.*, April, 1929, pp. 124–129.)

German version of the article referred to in May Abstracts, p. 274.

MESSUNG DER SCHALLDURCHLASSIGKEIT MIT HILFE DES HITZDRAHTMIKROPHONS (Measurement of Transparency to Sound by the Hot Wire Microphone).—H. Kietz. (*Physik. Zeitschr.*, 15th March, 1929, pp. 145–160.)

A DIRECT METHOD FOR THE STUDY OF THE CHARACTERISTICS OF AN ACOUSTIC TRANSMITTING SYSTEM.—K. Kobayashi. (*Journ. I.E.E.*, Japan, December, 1928, pp. 1337–1343.)

A method based on the use of a vibrometer provided with a rigid piston diaphragm. (*Cf.* January Abstracts, p. 46.)

ÜBER DEN NACHHALL IN GESCHLOSSENEN RÄUMEN (Echoes in Closed Spaces).—K. Schuster and E. Waetzmann. (*Ann. der Physik*, 12th March, 1929, Series 5, V. 1, No. 5, pp. 671–695); and BERECHNUNG DER SCHALLDICHTE IN EINEM KUGELFÖRMIGEN RAUME (Calculation of Sound Density in a Spherical Space).—K. Schuster. (*Ibid.*, pp. 696–700.)

A DIAPHRAGM-LESS MICROPHONE.—A. L. Foley. (*Sci. News-Letter*, 27th April, 1929, pp. 255–256.)

The sound waves are directed into the air space between two solid metal plates, causing alternating compressions and rarefactions of the air. These rapid changes in the density of the dielectric "permit corresponding electrical surges to cross the space." Development work is continuing and a patent has been applied for.

FIXED GRAIN CARBON MICROPHONE. (German Pat. 452961, Reisz.)

Grains of various sizes are stuck to the base in such a way that they are not covered by the adhesive medium.

BROADCAST RECEIVER FOR THE DEAF: A DESCRIPTION OF A SPECIAL LOUD SPEAKER UNIT WITH SOUND CONDUIT.—C. M. R. Balbi. (*Wireless World*, 8th May, 1929, V. 24, pp. 495–496.)

A LITTLE-SUSPECTED SOURCE OF DISTORTION.—W. F. Sutherland. (*Rad. Engineering*, April, 1929, V. 9, p. 45.)

"The effect on reproduction of loose laminations in the output transformer or impedance," particularly pronounced in push-pull arrangements, since here the direct-current component of the plate current has no effect in magnetising the core and thus adding to the mechanical stiffness of the laminations by tending to keep them spread apart.

DOES A VIBRATING DIAPHRAGM CARRY A MASS OF AIR WITH IT?—G. W. O.H. (*E.W. & W.E.*, March, 1929, V. 6, pp. 117–118.)

In calculations concerned with vibrating diaphragms such as those of loud-speakers, an addition is usually made to the actual mass of the diaphragm "to allow for the mass of the air which is moved with the diaphragm." The writer examines this point to see whether its usual acceptance as an obvious fact is justified, and concludes that the apparent attachment of a quantity of air to the diaphragm is "a convenient fiction which is only necessary in the case of divergent sound waves, because such waves cause a phase displacement between pressure and velocity which can be simulated by an increase of the mass of the diaphragm."

PHOTOTELEGRAPHY AND TELEVISION.

L'AMPLIFICATION DANS LA TÉLÉVISION (Amplification in Television).—G. H. D'Ailly. (*QST Franç.*, March, 1929, V. 10, pp. 45–51.)

The writer shows, from fundamental principles, how amplification in television presents difficulties which do not exist for sound-amplification thanks to the fact that the ear is not sensitive to phase-displacements, and also to the fact that sound reproduction does not involve the sudden large current-changes experienced in reproducing—say—the contour of an image. In a subsequent part he will apply these facts, and his analysis of them, to various common types of amplifier.

MARCONI-WRIGHT FACSIMILE SYSTEM.—G. M. Wright. (*Marconi Review*, January, February and March, 1929, pp. 5–6, 1–8 and 1–8.)

SULLA DIPENDENZA DALLA TEMPERATURA DELL' EFFETTO FOTOELETTRICO DI CONDUCIBILITA NEL JODURO MERCURICO (ROSSO) (On the Dependence on Temperature of the Photoelectric Effect on Conductivity, in Red Iodide of Mercury).—L. Piatti. (*Nuov. Cim.*, January, 1929, V. 6, pp. 14–35.)

ÉTUDE DE LA PRÉPARATION ET DES PROPRIÉTÉS OPTIQUES ET MAGNÉTO-OPTIQUES DES COUCHES TRÈS MINCES DE FER (Study of the Preparation and Optical and Magneto-optical Properties of Very Thin Films of Iron).—M. Cau. (*Ann. de Phys.*, April, 1929, V. 11, pp. 354–449.)

APPLICATION OF TALBOT'S LAW TO PHOTOELECTRIC CELLS WITH A NON-LINEAR ILLUMINATION-CURRENT CHARACTERISTIC.—G. H. Carruthers and T. H. Harrison and TALBOT'S LAW, FATIGUE, AND NON-LINEARITY IN PHOTOELECTRIC CELLS.—W. S. STILES. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 792–811 and 812–820.)

The writers of the first paper find that Talbot's Law (on the effect of intermittent light on the retina) holds for photoelectric cells even when these have a non-linear characteristic; which unexpected result they suggest is due to the non-linearity of these cells being due to "short-period" fatigue (*i.e.*, fatigue which occurs in the first few seconds after switching on the light). The second paper mathematically investigates this suggestion and shows that, making the "natural" assumptions about the form of the fatigue and recovery curves, obedience to the law implies that the initial response of the cell is proportional to the light-intensity.

and that in the case of non-linear cells the total amount of the fatigue is proportional to the square of the light-intensity.

SELENIUM AND CATHODE RAYS.—C. E. S. Phillips. (*Nature*, 4th May, 1929, V. 123, pp. 681–682.)

The writer has obtained evidence of direct action of cathode rays on the grey crystalline form of selenium; a rapid diminution of resistance taking place. Conditions of the experiment are described, and conclusions drawn.

BECQUEREL EFFECT IN CELLS CONTAINING GRIGNARD COMPOUNDS.—R. T. Dufford. (*Phys. Review*, No. 1, 1929, V. 33, pp. 119–120.)

Grignard reagents are organic magnesium halogen compounds. The greatest photoelectric effects are shown by solutions of those which display the strongest luminescence on oxidation.

ÜBER DEN EINFLUSS DES WASSERSTOFFS AUF DIE LICHTELEKTRISCHE ELEKTRONENEMISSION DES KALIUMS (The Influence of Hydrogen on the Photoelectric Electron Emission of Potassium) and WASSERSTOFFIONEN ALS URSACHE FÜR DAS AUFTRETEN DER LICHTELEKTRISCHEN SPEKTRALEN SELEKTIVITÄT DES KALIUMS (Hydrogen Ions as the Cause of the Photoelectric Spectral Selectivity of Potassium).—R. Suhrmann and H. Theissing and R. Suhrmann. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 52, pp. 453–463, and *Physik. Zeitschr.*, No. 22, 1928, V. 29, pp. 811–815.)

ÜBER DIE SÄTTIGUNG DES LICHTELEKTRISCHEN STROMES (On the Saturation of Photoelectric Current).—J. A. Becker. (*Naturwiss.*, 4th January, 1929, V. 17, p. 12).

A defence of the Becker-Müller theory against Suhrmann, who has attacked it on the grounds of his discovery that short wave light gives a saturation effect, while very long wave light produces a current increasing regularly with the applied voltage.

MEASUREMENTS AND STANDARDS.

HIGH-FREQUENCY MEASUREMENTS.—M. v. Ardenne. (*Elektrot. u. Masch:bau.*, 11th November, 1928 1929, V. 46, pp. 1086–1089.)

After a brief description of the technique of modern R.F. measurement, the writer describes the apparatus in his own laboratory. He lays stress on the multiple uses of the valve voltmeter and describes installations (using this instrument) for the measurement of the degree of amplification of R.F. amplifiers, of the logarithmic decrement of an oscillating circuit, and of the selectivity of a receiver. For the investigation of inter-electrode capacities, special apparatus is required. See also January Abstracts, p. 47.

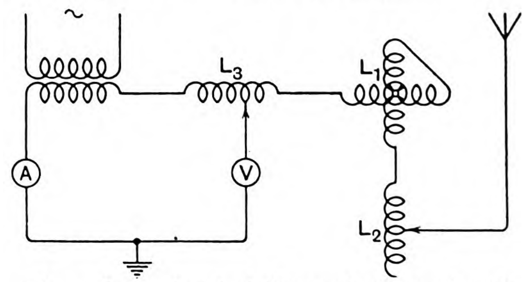
THE MEASUREMENT OF THE VOLTAGE AMPLIFICATION FACTOR OF TETRODES.—W. Jackson. (*E.W. & W.E.*, May, 1929, V. 6, pp. 252–254.)

"The use of a slightly modified form of Miller's alternating current bridge has enabled the values of μ_0 and R_p to be measured directly, simultaneously with the recording of the valve characteristic; so that their variation over the characteristic could be analysed at once."

Commenting on his results, the writer says that it would appear that a variation in anode voltage may be attended by a serious drop in the voltage amplification obtainable from a stage of R.F. amplification employing a four-electrode valve. "Since, however, the anode and screen voltages are in general taken from a common supply, the effect of a drop in battery pressure is not so serious . . ." curves indicating that the voltage amplification shows a slight decrease with decreasing anode and screen voltages, but that the mutual conductance increases at the same time; suggesting a probable increase in stage amplification together with a decrease in H.T. supply current required.

LA MÉTHODE CHIREIX POUR LES MESURES DE RÉSISTANCE EN HAUTE FRÉQUENCE (The Chireix Method for the Measurement of H.F. Resistances).—J. Morel. (*L'Industrie Élec.*, 10th November, 1928, V. 37, pp. 493–496.)

This method, depending on the very tight coupling of a resonant circuit with an oscillator, is said to have great advantages over the usual substitution and resonance curve methods; *e.g.*, the resonant circuit being tightly coupled is furnished with plenty of energy. Applied to the measurement of the R.F. resistance of an aerial, the arrangement is shown in the diagram.



The oscillator is set at the required wavelength, variometer L_1 and inductance L_2 being set so that the total aerial wavelength is much longer than this; A, therefore, shows no appreciable deflection. The inductances are then reduced until A shows a convenient deflection. The voltmeter tapping on L_3 is then adjusted for minimum deflection of V; under this condition, the readings of A and V give the resistance of the circuit to the right of the voltmeter. A second method uses a Chireix R.F. wattmeter.

THE CALIBRATION AND CONSTRUCTION OF A STANDARD FREQUENCY METER.—T. D. Parkin. (*Marconi Rev.*, April, 1929, pp. 18–28.)

A short description of the laboratory standard wavemeter adopted by the Marconi Company, together with an account of the method of calibration by alternator which is used for all accurate frequency measurements.

A LOGARITHMIC DEFLECTION INDICATOR.—M. B. Manifold and A. S. Radford. (*Journ. Scient. Instr.*, May, 1929, V. 6, pp. 145–151.)

An indicating instrument is described giving a deflection proportional to the logarithm of the input current over a current range of approximately 100 to 1 and a frequency range of 50 to 10,000 cycles. It is now accepted practice to measure such quantities as sound intensities in logarithmic units known as T.U.'s or decibels, so that the arrangement finds a wide application in the measurement of acoustical outputs of loudspeakers, transmission of complicated networks, and the like. The instrument is a vibration galvanometer which is fed by a constant-frequency current from a steady oscillator (50-frequency Hartley) through a special transformer; the state of saturation of the mumetal core of this is controlled by the current to be measured flowing in a third winding. The article includes reproductions of autographic records, of the frequency transmission of an electrical filter circuit set to cut off above 1,300 cycles, and of the response curve of a gramophone pick-up. Both these were taken by the use of a gramophone record having a continuously variable note.

EXPERIMENTS ON THE CORONA VOLTMETER.—H. B. Brooks and F. M. Defandorf. (*Bur. of Stds. J. of Res.*, October, 1928, V. 1, pp. 589–633.)

A description of work on a modified form of the Whitehead H.T. Voltmeter depending on the appearance of corona.

AUGMENTATION DE LA SENSIBILITÉ DES APPAREILS DE MESURES ÉLECTRIQUES À PIVOTS (Increasing the Sensitivity of Pivoted Electrical Measuring Instruments).—Quevron. (*Comptes Rendus*, 15th April, 1929, V. 188, pp. 1039–1041.)

The writer uses the stronger field obtainable with a saturated electromagnet and thus gains a greater sensitivity. The plan has hitherto been avoided because of the troublesome stray effects of the stronger field on the moving system, but this difficulty is overcome by a special design which renders the field strictly radial. On a first model, 10^{-8}A. or 10^{-5}v. could be "appreciated by direct reading."

"MEKAPION" VALVE ELECTROMETER FOR MEASUREMENTS AND AUTOMATIC RECORDING.—S. Strauss. (*Elektrot. u. Masch: bau*, 11th November, 1928, V. 46, pp. 1083–1086.)

An automatic method depending on the time of discharge of a condenser, applicable to the measurement of current, dosage of X-rays, illumination curves (by the use of photoelectric cells), study of ultraviolet rays in light (by the use of cadmium cells), etc.

ZUR KORREKTUR VON THERMOELEMENTEN BEI TEMPERATURSCHWANKUNGEN DER KALTEN LÖTSTELLE (The Correction of Thermoelements for Temperature Variations of the Cold Junction).—U. Retzow. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 164–168.)

MEASUREMENT OF THE INTENSITY OF HIGH FREQUENCY MAGNETIC FIELDS.—R. H. Mortimore. (*Phys. Review*, No. 1, 1929, V. 33, p. 113.)

Two methods of measurement, for a wavelength range of 12–30 m., are described; by measuring the voltage-drop in a standard inductance by a valve-voltmeter, and by a thermo-element.

UNTERSUCHUNGEN ÜBER DIE ANFANGSSTRÖME IM QUARZ (Investigations on the Initial Currents in Quartz).—A. D. Goldhammer. (*Zeitschr. f. Phys.*, No. 9/10, 1928, V. 52, pp. 708–725.)

Results of a photographic method of investigation were as follows:—in the first $4-7 \times 10^{-2}$ sec., the dependence on time of the initial current can be represented by the formula $i = a.t^{-n}$; later on, the current falls more rapidly. The current/voltage relation is not linear, but a curve whose slope varies in sense at different time-points. The superposition principle is not fulfilled. The reason is to be found in the conductivity of quartz varying with the current passing; it decreases in the direction of the current and increases in the opposite direction. After the crystal had been earthed for a time, the unipolarity of conductivity changed its direction. The author explains these phenomena by the presence of a number of "fast current-carriers," and the increase of their number under the influence of the passage of a current.

GENERAL PROPERTIES OF PIEZO-ELECTRIC QUARTZ AND THE VALUE OF A QUARTZ OSCILLATOR AS A FREQUENCY STANDARD.—S. Namba and S. Matsumura. (*Res. Electrot. Lab. Tokyo*, April, 1929, No. 248.)

In English. (1) Excitation for various modes of vibration:—(*a*) with two electrodes, Curie-cut and 30-degree cut crystals; superfluous and irregular vibrations; (*b*) with four electrodes using a four-electrode valve. (2) Observation of modes of vibration:—luminous discharge at resonance, lycopodium powder. (3) Frequency characteristics; influences of temperature; effects of air-gap; effects of circuit variations.

PIEZO-ELECTRIC RESONANCE-RELAY. (German Pat. 469209, *Radiofrequenz*, pub. 6th December, 1928.)

The luminous charges which are formed when a piezo-electric crystal is excited in a vacuum are used to release the discharge of some other A.C. or D.C. voltage, by means of auxiliary electrodes. Things can be so arranged that the released discharge either continues or ceases when the exciting influence stops. In certain cases the auxiliary electrodes can be dispensed with, the ordinary electrodes carrying the discharge.

NOTE ON A PIEZO-ELECTRIC GENERATOR FOR AUDIO-FREQUENCIES.—A. Hund. (*Bur. of Stds. Journ. of Res.*, February, 1929, V. 2, pp. 355–358.)

After enumerating five different ways of producing audio-frequency quartz-controlled oscillations without using very large crystals, the writer

describes and illustrates the method adopted, which consisted in the use of two independent piezo-electric oscillators beating together to give the required note; results suggest that the arrangement is as good as a tuning fork drive. He refers to the possibility of using only one generator and producing the audible frequency by harmonic division (*see* Abstracts, 1928, V. 5, p. 643).

Die Beeinflussung des piezoelektrischen Verhaltens einer Quarzplatte durch Radiumbestrahlung (The Effect of Radium Radiation on the Piezo-electric Behaviour of a Quartz Plate).—J. Laimböck. (*Mitt. Inst. f. Ra: forsch.*, No. 221a.)

The piezo-electric constant is considerably increased, to an extent almost proportional to the length of irradiation, by exposure to beta and gamma rays from a Ra preparation. After 7 days there was a rise from 0.6005×10^{-4} to 0.6710×10^{-4}. Left to itself, the quartz gradually returns to its normal condition. Repeated action leads to a decrease of the effect.

The Formula for the Optical Rotatory Dispersion of Quartz.—T. Bradshaw and G. H. Livens. (*Proc. Roy. Soc.*, 1st January, 1929, V. 122 A, pp. 245–250.)

After discussing the existing formulæ of Gumlich Kettler, Drude, Lowry and Coode-Adams, and their limitations, the writer proposes a new formula, more complex than Lowry's latest and most accurate one, which fits in with the latest experimental results: in particular, it provides an explanation of the practically constant effect of the infra-red band.

Elastic Constants of Fused Quartz. Change of Young's Modulus with Temperature. —H. D. H. Drane. (*Proc. Roy. Soc.*, 1st January, 1929, V. 122 A, pp. 274–282.)

When fused quartz is heated, its elastic constants for stretch shear and bulk change all increase, a sharp distinction in behaviour from that of most other elastic solids. The present paper deals with the determination of Young's modulus, and a comparison of the results with those of other workers leads to the conclusion that there must be actual variability of the modulus from one specimen to another. "There remains as a problem the specification of the precise thermal and mechanical treatment necessary to yield a specimen of fused quartz with fixed mechanical and optical characteristics"—for there appears to be some close relationship between the optical anomalies found by Rayleigh in examining specimens of vitreous silica, and the irregularities in mechanical behaviour.

Magnetostriction in Nickel Steels.—J. S. Rankin. (*Journ. R. Tech. Coll. Glasgow*, January, 1929, pp. 12–19.)

Magnetostriction and the Phenomena of the Curie Point.—R. H. Fowler and P. Kapitza. (*Proc. Roy. Soc.*, 2nd May, 1929, V. 124 A, pp. 1–15.)

An investigation of Heisenberg's theory of ferromagnetism (Abstracts, 1928, V. 5, p. 647) to see whether it can "also provide a natural home for the associated phenomena of the Curie point and for magnetostriction." The writers say: "As a result we think we may claim that the change of size at the Curie point and magnetostriction will both fit satisfactorily into Heisenberg's theory. We cannot, of course, go beyond a very rough quantitative comparison."

Sur un Chronographe enregistrant le Dix-millième de Seconde (A Recording Chronograph registering the Ten-thousandth of a Second).—P. Lejay. (*Comptes Rendus*, 22nd April, 1929, V. 188, pp. 1089–1091.)

This instrument is for use with the author's free-swinging pendulum, which depends on capacity-interaction between an oscillator and an amplifier for its supply of energy.

Influence of a Vacuum on the Radium Clock.—S. Borovik and Afanasjeva. (*Leningrad Comptes Rendus*, No. 24, 1928.)

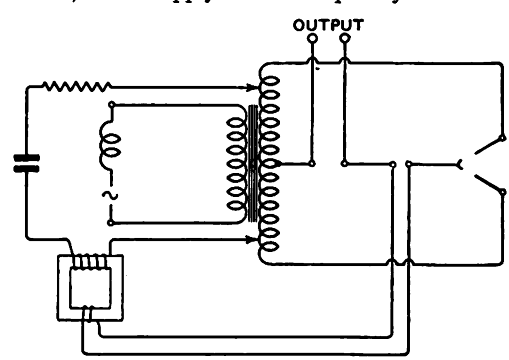
The Establishment of a General Formula for the Inductance of Single-turn Circuits of any Shape.—V. I. Bashenoff. (*E.W. & W.E.*, May, 1929, V. 6, pp. 245–251.)

Über ein Vervahren zur Beurteilung statischer Häufigkeitskurven (A Procedure for the Judging of Static Frequency- or Distribution-Curves).—H. C. Plaut. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 175–177.)

SUBSIDIARY APPARATUS AND MATERIALS.

Hochfrequenz-Gleichrichter-Anlage mit automatischer Konstanthaltung der Gleichspannung (H.F. Rectifying Plant with Automatic D.C. Voltage Stabilisation).—P. Hermanspann. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 121–127.)

The object was to obtain a high tension (over 20 kv.) D.C. supply more adequately smoothed



than usual and with stabilised voltage under varying load. For the sake of better smoothing, a Lorenz single-phase generator was used, giving 8,000 p.p.s. Comparative tests were made of air-cored and iron-cored transformers (ring-shaped, to reduce leakage). The latter—whose core was

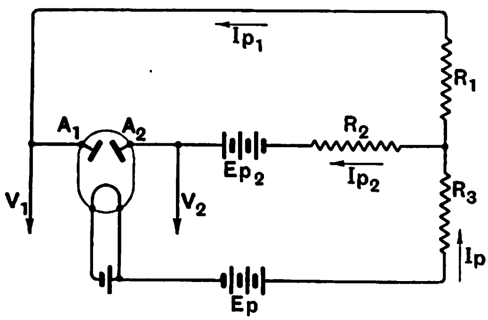
of the very thinnest sheets of "high-frequency iron" such as are used in static frequency-changers —showed a marked superiority.

The voltage stabilisation was performed by shunting the working-circuit by a variable reactance-circuit, and allowing the working current to vary the reactance in such a way as to keep the voltage constant. This was done by passing the (rectified) working current through an auxiliary winding of the iron-cored choke in the reactance-circuit, as shown in the diagram.

As will be seen from the diagram, the reactance-circuit is not right across the transformer secondary but is tapped down; otherwise, the resistance in this circuit would have to be large to keep down the additional load, and this would spoil the sharpness of compensation. Curves are given showing the excellent voltage-stabilisation during a change of output from 1 to 6 amps. (All these tests were on an output voltage of about 80 v. only, for ease of measurement).

TRIODE JUMPER.—H. Nukiyama and K. Nagai. (*Tech. Rep. Tôhoku Imp. Univ., Sendai*, 1929, No. 2, V. 8, pp. 31–39.)

The flow of secondary electrons from "emitting anode" A_1 is gathered to the "collecting anode" A_2: if R_1, R_2 and R_3 are properly chosen, I_{p1} decreases, and at the same time I_{p2} increases discontinuously, when E_p is increased continuously, so that "jumping" phenomena arise.



If the actuating potential is added to E_p, and one or more of the various currents flow through the coils of an electromagnetic relay, a jumping relay is obtained. The three electrodes may be provided by an ordinary triode, or tetrode (the surplus electrode, in the latter case, being kept at a proper potential.) Instead of working the relay directly, the circuit may be connected to a second valve in whose plate circuit the relay functions. Regarding applications, the author says that the relay armature "may be applied to a printing machine directly or be used as a switch of a second relay. The writer also used a relay of this kind with a constant temperature furnace and a constant frequency oscillator and has obtained good results." Mention is also made of use in multiplex telegraphy.

ON THE CAPACITY OF DRY ELECTROLYTIC CONDENSERS.—P. R. Coursey. (*E.W. & W.E.*, March, 1929, V. 6, pp. 128–132.)

LES PILES ÉLECTRIQUES D'APRÈS LES BREVETS RÉCENTS (Primary Batteries according to Recent Patents).—L. Jumau. (*Rev. Gén. de l'Élec.*, 27th April, 1929, V. 25, pp. 649–662.)

This paper describes in some detail not only many recent types of cells, wet and dry, but also various methods of manufacture. It is to be continued.

EIN NEUER GLIMMLICHTRÖHREN GLEICHRICHTER (A New Glow-discharge Rectifier).—J. Preuss. (*Rad. f. Alle*, May, 1929, pp. 220–221.)

Description of the Seibt "Anotron D," for full-wave rectification up to 250 mA. at 1,000 v.

NEUE GLIMMLICHTGLEICHRICHTER (New Glow-discharge Rectifiers).—K. Teucke. (*Zeitschr. f. Hochf. Tech.*, April, 1929, V. 33, pp. 145–148.)

A paper on the Seibt "Anotron."

DIE CASTINGS IN THE MODERN RADIO.—L. H. Pillion. (*Rad. Engineering*, April, 1929, V. 9, pp. 34–37.)

"A short history of metal moulding and detailed data on present-day die casting as applied to modern industry."

ANALYSIS OF PAPERS EMPLOYED IN RADIO MANUFACTURING. I.—THE MICROSCOPE AS AN ASSET IN THE RADIO LABORATORY.—I. L. Gartland. (*Rad. Engineering*, April, 1929, V. 9, pp. 27–32.)

SPARKLESS COMMUTATION.—(French Patent, 651741, Igra, published 27th February, 1929.)

To prevent sparking of small machines worked near wireless receivers, all the segments of the commutator are connected together through suitably high resistances—this is arranged by cutting a groove round the commutator and filling it with a semi-conducting material.

RECORDING BY PERFORATING.—M. Metfessel. (*Science*, 5th April, 1929, V. 69, pp. 382–383.)

The use of a pin to replace various types of fountain pen and pencil recorders is recommended as requiring no adjustments or refillings. Such a method has been very successfully used for tuning-fork recording.

AN X-RAY TUBE WITH DETACHABLE ENDS AND ELECTRODES.—W. Band and A. J. Maddock. (*Journ. Scient. Instr.*, May, 1929, V. 6, pp. 160–163.)

A BRAUN TUBE HYSTERESIGRAPH.—J. B. Johnson. (*Bell Tech. Journ.*, April, 1929, V. 8, pp. 286–308.)

A cathode-ray oscillograph is combined with an amplifier and an electrical integrating circuit (condenser and resistance) for the purpose of observing hysteresis loops of magnetic materials. Alter-

nating flux as low as one maxwell may be readily observed.

OSCILLOGRAPHS FOR RECORDING TRANSIENT PHENOMENA.—W. A. Marrison. (*Bell Tech. Journ.*, April, 1929, V. 8, pp. 368–390.)

See June Abstracts, p. 341.

STATIONS, DESIGN AND OPERATION.

DER GLEICHWELLEN-RUNDFUNK (Common Wave Broadcasting).—W. Hahnemann and F. Gerth. (*E.N.T.*, April, 1929, V. 6, pp. 151–157.)

Discussing the advantages and disadvantages of the two possible ways of common wave broadcasting (the system of independent transmitters where the carrier waves are kept constant by the personnel at each station—they must not differ by more than about 15 p.p.s. — and the system in which the carrier frequency is distributed from a central station) it is stated that tests show that the interference zone stretches over more than 90 per cent. of the distance between two stations for the former system, and over only 15 per cent. for the latter. The rest of the paper deals with the Lorenz System now being tried for the district E. Berlin, Stettin and Magdeburg. It concludes by the remark "It must be left to the future to see whether the experience gained will lead to a wide system of common wave transmitter groups. In particular, a decision is needed with regard to the still open question—whether the modulation to all the transmitters must be kept in phase by the introduction of artificial cable."

MARCONI PORTABLE SHORT-WAVE MILITARY TRANSMITTER AND RECEIVER, TYPE S.A.I. (*Marconi Rev.*, October, 1928, pp. 13–22.)

A 25–40 w. set, 7–8 m. wave-range, for telephony and I.C.W. An account of its development and performance is given in the December issue.

LAY-OUT AND TESTS OF A SHORT-WAVE TRANSMITTER. PART I—DESIGN; PART II—RESULTS OF TESTS.—E. Takagishi, E. Iso and S. Kawazoe. (*Res. Electrot. Lab. Tokyo*, Nos. 243 and 246.)

In Japanese. The transmitter is capable of delivering about 1 kw., for a wave-range of 30–40 m., for telephony.

LES CODES MÉTÉOROLOGIQUES (The Meteorological Codes). (*QST Franç.*, March, 1929, V. 10, pp. 33–40.)

Final part of the series whose first part was dealt with in March Abstracts, p. 165.

RADIO SIGNAL TRANSMISSIONS OF STANDARD FREQUENCY, MARCH TO JULY. (*Bureau of Stds., Tech. News Bull.*, March, 1929, No. 143, pp. 22–23.)

A new schedule of signals from WWV. The modulated signals hitherto sent are being replaced by C.W.

EFFECT OF SIGNAL DISTORTION ON MORSE TELEGRAPH TRANSMISSION QUALITY.—J. Herman. (*Bell Tech. Journ.*, April, 1929, V. 8, pp. 267–285.)

GENERAL PHYSICAL ARTICLES.

THE PROBLEM OF THE INTERACTION OF RADIATION AND THE ELECTRON.—R. D. Kleeman. (*Science*, 5th April, 1929, V. 69, pp. 380–381.)

The writer claims to have solved this problem through his deductions, from thermodynamical investigations,of the following electron properties :—(*a*) Possession of internal apart from kinetic energy; (*b*) two different ways of radiation; firstly, on undergoing acceleration, and secondly, on emitting a part of its internal energy as radiation not necessarily connected with its motion; (*c*) the slowing down of its motion and hence increase in internal energy due to the surrounding radiation; (*d*) the force acting upon it when placed in an electric field depends on its internal energy, and in a general way decreases with it. It may therefore happen that under certain conditions it does not possess any electric field at all. "By means of these results and the laws of conservation of energy and momentum, and that radiation is *emitted* in quanta (the nature of the process of emission of radiation does not seem to be determined by thermodynamics), the various phenomena on the interaction of radiation and the electron may be explained—at least there is nothing the writer has not, so far, brought into line. For example, all the inherent difficulties of the Bohr atom, and its antagonism to the Lewis, Langmuir atom, completely disappear. The results thus furnish the solution of a problem in physics and chemistry that has absorbed the attention of scientists for the last thirty years."

THERMODYNAMICAL PROPERTIES OF THE ELECTRON, AND ATOMIC THEORY.—R. D. Kleeman. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 493–504.)

"It appears from this paper that electromagnetic radiation may spread evenly in space, and may be absorbed by electrons and atoms in indefinite amounts, which appear in the form of internal energy. This energy may be radiated in part or altogether into space, but only as a continuous train of waves whose energy is equal to $h\nu$. With this as basis, all radiation phenomena may be explained, of which an outline has been given in this paper."

QUANTUM THEORY OF ATOM DISRUPTURE.—G. Gamow. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 52, pp. 510–515.)

An investigation of the radioactive and artificial disintegration of atoms according to the principles of wave mechanics. It is concluded that for disintegrable elements a proton is almost always split off when an alpha particle penetrates the nucleus. The probabilities of penetration for heavier atoms, such as iron, are found to be infinitesimal (using *RaC′* alpha particles), a result completely disagreeing with the ideas of the Viennese workers. An outline of the above in-

vestigation, containing further points, is given in *Nature*, 24th November, 1928, V. 122, pp. 805–806.

THE STRUCTURE OF ATOMIC NUCLEI.—(*Nature*, 16th February, 1929, V. 123, pp. 246–248.)

A summarised account of the discussion at the Royal Society on 7th February.

SUR LA THÉORIE SYNTHÉTIQUE DES CHAMPS (The Synthetic Field Theory).—A. Einstein. (*Rev. Gén. de l'Élec.*, 27th April, 1929, V. 25, pp. 644–648.)

A translation of the Unified Field Theory paper, with an introduction by de Donder.

INFLUENCE OF A MAGNETIC FIELD ON THE DIELECTRIC CONSTANT.—J. J. Weigle; and DIELECTRIC ANISOTROPY.—M. Jezewski. (Summarised in *Science Abstracts*, Sec. A., 25th March, 1929, p. 272.)

LES THÉORIES MODERNES DU MAGNÉTISME (Modern Theories of Magnetism).—L. Bruninghaus. (*Rev. Gén. de l'Élec.*, 9th and 16th February, 1929, V. 25, pp. 197–210 and 237–244.)

The writer concludes that the most diverse tests (Weiss, Cabrera, Honda and others) on substances extremely varied in chemical nature and physical state show that in almost every case the atomic moments are whole multiples of an elementary moment which may be called the "experimental magneton." It now remains to find the relation between this and the theoretical Bohr magneton. This perhaps may be done by finding what modifications the quantic conditions undergo in passing from the free atom of a diluted vapour of silver to the firmly-bound atom of a crystal of iron.

UNE HYPOTHÈSE SUR LA NATURE DE L'HYSTÉRÉSIS (A Hypothesis as to the Nature of Hysteresis).—A. Guilbert. (*Rev. Gén. de l'Élec.*, 5th January, 1929, V. 25, pp. 7–17.)

A thermodynamic theory of hysteresis.

ENKELE METINGEN OVER HET BARKHAUSEN-EFFEKT (Some Measurements on the Barkhausen Effect).—G. J. Sizoo. (*Physica*, February, 1929, pp. 43–50.)

DIE POLARISATION DES ELEKTRONSTOSSLEUCHTENS BEI EDELGASEN (The Polarisation of the Electron-impact Light in the Inert Gases).—K. Steiner. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 52, pp. 516–530.)

CHART OF THE ELECTROMAGNETIC ENERGY RELATIONS.—W. E. Deming. (*Journ. Opt. Soc. Am.*, January, 1929, V. 18, pp. 50–52.)

A tabulation and a graph, both designed for the rapid answer of such questions as "What frequency corresponds to an electron having a speed of 500 volts?" or "What is the fractional relativity increase in transverse mass of a body moving with a speed of 2×10^{10} cm./sec.?" The wavelengths range from beyond the longest electric waves to beyond the shortest possible wavelength from an oscillating electron (corresponding to a frequency of about 3×10^{22} on the classical theory).

ON THE ELECTROMAGNETIC FIELD OF AN ELECTRON.—THE ELECTRON AS A GRAVITATIONAL PHENOMENON.—D. Meksyn. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 425–433.)

SYMPOSIUM ON QUANTUM MECHANICS.—(*Journ. Franklin Inst.*, April, 1929, V. 207, pp. 449–542.)

Fourteen papers read before the American Physical Society.

THE RELATIVITY THEORY OF DIVERGENT WAVES.—O. R. Baldwin. (*Proc. Roy. Soc.*, 6th March, 1929, V. 123 A, pp. 119–133.)

THE QUANTUM THEORY.—H. S. Allen. (*Nature*, 8th December, 1928, V. 122, Supplement pp. 887–894.)

Light Quanta: the Radiation Problem: Integral Relations in Science: the Rutherford-Bohr Atom: the Quantum Postulates: Matrix Mechanics: Wave Mechanics: the New Outlook.

THE PHYSICAL INTERPRETATION OF WAVE MECHANICS.—G. Temple. (*Proc. Physical Soc.*, 15th December, 1928, V. 41, Part I, pp. 60–82.)

Author's abstract: "The object of this paper is to give an account of the fundamental principles of wave mechanics in a manner which shall make clear the physical significance of all the quantities and processes involved. The principles are illustrated by discussions of the propagation of free electric waves in uniform electromagnetic fields and of bound electric waves in the hydrogen atom. The paper concludes with relativistic wave mechanics (prior to the work of Dirac and Darwin) and a short account of the Compton effect." Later on he says: "Modern quantum theory is content with the quantisation of the optical energy transferred in processes of emission and absorption, and contemplates with equanimity the possibility that free radiation may be governed only by classical laws of continuity. It will be shown in this paper that a similar self-denying ordinance may be welcomed in the theory of electrons."

THE FUNDAMENTALS OF ELECTRODYNAMICS.—W. F. G. Swann. (*Journ. Franklin Inst.*, November, 1928, V. 206, pp. 571–595.)

NEUE WEGE IN DER PHYSIK (Fresh Paths in Physics).—E. Schrödinger. (*E.N.T.*, December, 1928, V. 5, pp. 485–488.)

An address recently delivered in Berlin.

HEATS OF CONDENSATION OF ELECTRONS ON PLATINUM IN IONISED HE, NE, AND A.—C. C. Van Voorhis and K. T. Compton. (*Phys. Review*, June, 1928, V. 31, p. 1122.)

Measurement of the Charge of Positive Ions by the Shot Effect.—N. H. Williams and W. S. Huxford. (*Phys. Review*, June, 1928, V. 31, pp. 1120–1121.)

Messung der Wärmeentwicklung bei der Kondensation von Elektronen in Metallen (Measurement of the Heat developed by the Condensation of Electrons in Metals).—R. Viohl. (*Ann. d. Physik*, No. 18, 1928, V. 87, pp. 176–196.)

A description of the apparatus and method successfully employed.

Les Pellicules sphériques électrisées et les Orbites privilegiées de Bohr-Sommerfeld (The charged spherical particles and the Bohr-Sommerfeld "preferential orbits"). —L. Décombe. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 823–826.)

In previous communications the author has connected the spectral emission with the beats occurring between the true pulsations of the electrons which follow these orbits. The present note, combined with the previous work, is designed to "safeguard the undulatory point of view by making it penetrate—in a simple and concrete form—into a domain which has been taken possession of by the theories of emission with a success more apparent than real." A simple physical interpretation is found for the Rydberg constant, as was done before for the Planck constant.

The Wave Theory of the Electron.—J. M. Whittaker. (*Proc. Camb. Phil. Soc.*, October, 1928, V. 24, pp. 501–505.)

Dirac has shown how the "duplexity" phenomena of the atom can be accounted for without recourse to the hypothesis of the spinning electron, using the methods of non-commutative algebra. Darwin has given an alternative presentation of the theory, using the methods of wave mechanics; his work can only be given invariance of form at the expense of much additional complication, the four wave functions used by him having to be replaced by sixteen. The present paper describes a method avoiding this difficulty.

Étude des Radiations Sécondaires observées dans la Diffusion Moléculaire de la Lumière par les Fluides—Effet Raman (Study of the Secondary Radiations observed in the Molecular Diffusion of Light by Liquids—Raman Effect).—P. Daure. (*Comptes Rendus*, 5th November, 1928, V. 187, pp. 826–828.)

By photometric research on halogen derivatives of arsenic and phosphorus, the writer has measured the ratio of the intensities of the positive and negative rays, and the ratio of two secondary rays of the same frequency excited by two different radiations. Regarding the former ratio, Venkateswaren had proposed an exponential formula to connect this with the exciting frequency. The equation which seems to fit in with the observed results is $r = e^{-\frac{n}{21.7}}$ where r is the ratio and n the exciting frequency in wavelengths per millimetre. Results with the second ratio show that the secondary ray increases uniformly with the exciting frequency, but does not follow the N^4 law of molecular diffusion.

Zur Theorie der Ionisation in Kolonnen (On the Theory of Ionisation in Columns).—G. Jaffé. (*Ann. der Phys.*, 19th April, 1929, Series 5, V. 1, No. 7, pp. 977–1008.)

An extension of the writer's 1913 and 1914 papers on his theory.

The Adsorption of Hydrogen on the Surface of an Electrodeless Discharge Tube.—M. C. Johnson. (*Proc. Roy. Soc.*, 6th April, 1929, V. 123 A, pp. 603–613.)

Most experiments on the disappearance of gas from discharge tubes are complicated by loss and gain at metal surfaces. Here, the action of hydrogen on glass alone is isolated by the use of the electrodeless discharge: this eliminates internal metal electrodes, and also external "ozoniser" type electrodes which may be open to the objection of allowing slight electrolytic liberation of gases from the glass.

The Mechanism of Spark Discharge.—L. J. Neuman. (*Proc. Nat. Acad. Sci.*, March, 1929, V. 15, pp. 259–265.)

MISCELLANEOUS.

Sur la Théorie Électronique des Mauvais Contacts (On the Electronic Theory of Imperfect Contacts).—H. Pélabon. (*Comptes Rendus*, 25th February, 1929, V. 188, pp. 620–622.)

When two conductors are in perfect contact and a field is in existence, the free electrons move in a combined motion with a very great velocity, and Ohm's law is fulfilled. If, on the other hand, the conductors are separated by a very small gap into which the superficial electronic layers penetrate, an "evaporation" of electrons takes place on one of the surfaces and a "condensation" on the other; this method of transportation is much slower, and depends on the strength of the field. Using the mechanism just described, the writer accounts for "all the facts observed with imperfect contacts"; dealing first with D.C., then with A.C.—where he obtains a formula for the rectified current which agrees with his experimental results, and also accounts for the rectifying effect of electrodes in which the only lack of symmetry is that one is more mobile than the other (*see* H. Pélabon, Abstracts, 1929, p. 226)—and finally with H.F. currents, including damped waves. Here, as with the fixed-mobile contacts, the mechanical effect of the electrostatic pressure is called into play. In the above cases the rectified current is in the direction towards the better conductor (towards the mobile conductor in the "symmetrical" fixed-mobile contacts), but it may happen with high frequencies that the mobile electrode rebounds—in which case the rectification is towards the less conducting electrode, as Branly found with PbO_2.

THE EFFECT OF ULTRA-VIOLET AND X-RAYS ON THE STEADY CURRENT CHARACTERISTICS OF CRYSTAL DETECTORS.—W. Jackson. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 866–873.)

Ogawa (Abstracts, 1928, V. 5, p. 527) attributes crystal-detector action to the difference of electron emissions from the two electrodes. Palmer suggests that this "cold vacuum tube" analogy is supported by the observed phenomena that improved rectifying properties are obtained when the tendency for electronic emission is increased (*e.g.*, by a small steady potential in the right direction; by heating; by the addition of a small quantity of an impurity, etc.). The writer describes experiments where the effect is tested of rays which should decrease the work necessary to remove an electron, and which therefore might be expected to affect the rectifying property. The effect of ultra-violet rays is to increase conductivity and to decrease slightly the maximum curvature of the characteristic, thus slightly reducing the rectifying properties at the point of best rectification. X-Rays produce on most of the contacts tested the above effect on an exaggerated scale, the unidirectional and rectifying properties being completely destroyed, with no sign of returning after several hours of rest. With a carborundum-steel combination the loss of unidirectional property is noticeable although the rectifying property is retained.

ON THERMOELECTRIC PHENOMENA OF THIN METALLIC FILMS.—T. Terada, S. Tanaka and S. Kusaba. (*Proc. Imp. Acad. Tokyo*, No. 4, 1927, V. 3, pp. 200–203.)

Thin films (5–10μ) show various thermoelectric effects with local heating; for example, if half of a silver film is thicker than the other half; a thermocurrent flows from thin to thick.

THE THEORY OF ELECTRICAL RECTIFICATION.—R. de L. Kronig. (*Nature*, 2nd March, 1929, V. 123, p. 314.)

The resistance of a metallic conductor is caused by the transfer of momentum, which the conduction electrons have gained under the influence of the applied electric field, to the ions of the crystal lattice—through collisions; or in the language of wave mechanics, by the scattering of the waves representing the conduction electrons under the action of these ions. Rectification signifies here, therefore, a difference in the scattering power of the circuit for electron waves travelling in opposite directions. The writer suggests that crystal rectification is due to asymmetrical binding of the ions into positions of equilibrium by restoring forces not symmetrical for equal and opposite displacements; such asymmetrical binding would come into play particularly near the boundary, and still more at the edges and corners, of a crystal lattice; it has already been shown to exist even in the interior of certain (rectifying) crystals, by X-ray analysis. The theory thus envisages the possibility of volume rectification (not yet found experimentally) in addition to the usual surface rectification. It would explain the damage to the rectifying property of a point-to-crystal contact when the point is pressed tightly against its base, for in this process the sharp corners are flattened out.

CRYSTAL CLASSIFICATION BY PIEZOELECTRIC TEST.—W. Schneider. (*Zeitschr. f. Phys.*, No. 3/4, 1928, V. 51, pp. 263–267.)

In investigating crystal structure it is often important to know whether the crystal is centro-symmetrical or not. If piezoelectric effects are found the crystal can at once be classed as lacking a centre of symmetry. Test apparatus is described and a list of results given.

DER KUPFERJODÜRDETEKTOR (The Copper Iodide Detector).—E. Habann. (*Zeitschr. f. tech. Phys.*, January, 1929, pp. 25–28.)

Investigation of a new detector, from the results of which various generalisations are drawn as to what ionic properties make a good detector material.

LE SENS DU COURANT REDRESSÉ PAR UN DÉTECTEUR À CRISTAL (The Direction of the Current rectified by a Crystal Detector).—G. G. Reisshaus. (Summary in *L'Onde Élec.*, March, 1929, V. 8, p. 21A.)

The apparently arbitrary direction of the rectified current, found for example with a copper wire and galena couple, is explained by the theory that the current always flows from the more pointed to the more rounded electrode; the crystal surface being very irregular, with small sharp angles, may—contrary to appearances—be more pointed than the copper wire. The same explanation accounts for the rectifying effects of apparently identical electrodes, *e.g.*, two polished metallic balls. *Cf.* Pélabon and Krönig, above.

THEORETISCHES UND EXPERIMENTELLES ZUM JOHNSON-RAHBEK-EFFEKT (Theoretical and Experimental Investigation of the Johnson-Rahbek Effect).—P. Böning. (*Zeitschr. f. Fernmeld: tech.*, 29th April, 1929, V. 10, pp. 49–55.)

MAN-MADE STATIC: HIGH-VOLTAGE OVERHEAD ELECTRICAL TRANSMISSION LINES AND RADIO INTERFERENCE.—R. L. Smith-Rose. (*Wireless World*, 8th May, 1929, V. 24, pp. 476–480.)

Part I.—Summary of Knowledge and Experience on the Interfering Effects of Overhead Line Networks in Radio Communication. "From the available information as summarised above, it may be fairly definitely concluded that at a wireless receiving station situated outside a minimum distance of the order of half-a-mile from a high voltage overhead distribution line, no interfering or disturbing effects will be experienced due to the existence of the line or the current which it is carrying. The only point upon which no definite information has been traced is the effect of spark discharges from the line on a receiving

station not less than half-a-mile away. . . ." This point is dealt with in Part II.—Some Experiments on the Interference Effect of a High-voltage Spark Discharge on a Radio Receiver. "It appears that the minimum distance of half a mile of a wireless receiver from the line, chosen on other grounds [see above] will also ensure freedom from the disturbing effects of spark or arc discharges, except when the receiving station is in electrical connection with the line. In such a case, as previously mentioned [in Part I, where it was pointed out that such connection might reduce the effective distance from the line], the use of special filter circuits in the connection might be necessary and would probably be effective."

PREVENTION OF INTERFERENCE BETWEEN POWER AND COMMUNICATION LINES: PROGRESS IN GERMANY IN 1928.—W. Wagner. (*E.N.T.*, March, 1929, V. 6, pp. 116–117.)

FORMULES RELATIVES À L'ÉTUDE DES BRUITS D'INDUCTION SUR UNE LIGNE DE TÉLÉCOMMUNICATION INFLUENCÉE PAR UNE LIGNE DE TRANSMISSION D'ÉNERGIE (Formulæ regarding Induction Noises in a Communication Line induced by a Power Line).—J. B. Pomey. (*Rev. Gén. de l'Élec.*, 13th April, 1929, V. 25, pp. 555–561.)

MESSUNG DER FERNSPRECHSTÖRWIRKUNG VON STARKSTROMLAGEN (Measurement of Power Station Interference with Telephonic Communication.—L. Roehmann. (*E.T.Z.*, 21st March, 1929, pp. 424–426: Discussion, pp. 432–434.)

HIGH-TENSION MEASUREMENTS AND THEIR TRANSMISSION TO A DISTANCE.—A. Palm. (*Rev. Gén. de l'Élec.*, 23rd March, 1929, V. 24, pp. 463–464.)

French summary of a German paper.

SYSTEMS OF SELECTIVE DISTANT CONTROL.—Y. Shimazu. (*Journ. I.E.E. Japan*, November, 1928, pp. 1213–1231.)

A survey of various methods in use in Europe and America, including the author's own system.

CARRIER TELEPHONE SYSTEM FOR SHORT TOLL CIRCUITS.—H. S. Black, M. L. Almquist, and L. M. Ilgenfritz. (*Journ. Am. I.E.E.*, January, 1929, V. 48, pp. 15–20.)

"Type D" system is described for circuits of shorter lengths than could be spanned economically by the multi-channel types in use for longer distances. It gives one additional telephone circuit per pair of wires, and the equipment can be moved easily from place to place.

WIRED WIRELESS "MONOPHONE" TELEPHONY.—(*Nature*, 11th May, 1929, V. 123, p. 733.)

A paragraph on "a notable invention" announced to the National Academy of Sciences by Squier, the inventor of "wired wireless." The new method, which is called the "monophone," is said to be the perfection of a form of radio guided by telephone lines. "The power taken by a small incandescent lamp would be sufficient to supply five thousand telephones. . . . There would be no difficulty in receiving sound-motion pictures and television." *Cf.* Abstracts, January, p. 53 (O.F.B.) and February, p. 116.

A VOICE FREQUENCY MULTI-CHANNEL TELEGRAPH SYSTEM.—J. M. Owen and J. A. S. Martin. (*P.O. Elec. Eng. Journ.*, January, 1929, V. 21, pp. 267–275.)

A description of the system developed by the G.E.C. with the co-operation of the Post Office. Six separate high speed circuits are provided for telegraph working on a loaded underground cable or other telephone circuit normally adapted to four-wire working. Valve-controlled tuning forks (Eccles and Jordan) are used.

THE TRANSMISSION OF HIGH-FREQUENCY CURRENTS FOR COMMUNICATION OVER EXISTING POWER NETWORKS.—C. A. Boddie and R. C. Curtis. (*Proc. Am. I.E.E.*, January, 1929, V. 48, pp. 37–41.)

The use of tuned choke coils to isolate the communication channel from the remainder of the power system is here treated. Formerly, the natural changes in line characteristics due to switching were so great that a satisfactory communication circuit could not be obtained.

ÜBER DIE STÖRWIRKUNG VON WANDERWELLEN UND DIE GEGENSEITIGE BEEINFLUSSUNG VON TELEGRAPHENLEITUNGEN (The Interference Effects of Surges and the Interaction of Telegraph Lines).—K. Ohashi. (*E.N.T.*, January, 1929, V. 6, pp. 1–8.)

A theoretical investigation.

SOME ADSORPTION ISOTHERMALS FOR A PLANE PLATINUM SURFACE.—W. G. Palmer. (*Proc. Roy. Soc.*, 4th February, 1929, V. 122 A, pp. 487–497.)

The method of the electric coherer has been employed to determine the adsorption isothermals of some typical substances. Incidentally it is mentioned that a pure paraffin hydrocarbon of less than 5 carbon atoms in its chain forms on platinum a film so loosely held that the cohering voltage is practically zero.

LUMINOUS DISCHARGE IN GASES AT LOW PRESSURE.—H. Petterson. (*Nature*, 9th March, 1929, V. 123, p. 346.)

Using oscillations of frequency 10^8, and tubes of transparent silica, the writer has obtained the electrodeless discharge in tubes of only 5 mm. diameter under pressures much less than 10^{-5} mm. of mercury. Various effects are described, one of these being only explicable on the assumption that the silica is decomposed, releasing oxygen, by the action of ultra-violet light of very short wavelength generated at the discharge.

LE GRAND ELECTRO-AIMANT DE L'ACADÉMIE DES SCIENCES (The Great Electro-magnet of the Academy of Sciences).—A. Cotton and G. Mabboux. (*Recherches et Inventions*, December, 1928, pp. 453–524.)

A very full illustrated description of the construction and installation of the magnet referred to in Abstracts, 1928, V. 5, p. 529.

RADIOMETER FOR LIGHT FROM PLANETS AND STARS.—C. G. Abbot. (*Sci. News-Letter*, 27th April, 1929, pp. 255–256.)

The moving system is constructed of very small pieces cut from a fly's wing, and is suspended on a very fine quartz thread. Swing is measured by a very small beam reflected from a mirror on to a scale 20ft. distant. "It has been possible to detect the force and analyse the variety of light . . . from stars as small as 3.5 magnitude."

AN INTENSITY GAUGE FOR "SUPERSONIC" RADIATION IN LIQUIDS.—W. T. Richards. (*Proc. Nat. Ac. Sci.*, April, 1929, V. 15, pp. 310–314.)

"The high-frequency sound waves of high intensity . . . recently developed by Wood and Loomis . . . have produced effects in liquid systems, some of which are extremely difficult to account for on the primary properties of compressional waves. Notably the increase in (chemical) reaction velocities . . . has at present no direct or plausible explanation." A reliable measure of the intensity of such compressional waves is a necessary factor in exploring such effects, and the writer describes various attempts to find a satisfactory method :—maintaining a weighted reflecting disc in position : rise in temperature due to absorption of the waves : change in volume of manometric bulbs : retardation of flow of liquid in a capillary tube, etc., etc. The method actually adopted depended on the ear-trumpet principle, the concentrated sound energy being measured as hydrostatic pressure : a small funnel was blown on the end of a capillary tube and immersed in the liquid, the upward displacement of the capillary meniscus giving a measure of the wave-intensity.

CORONA ELLIPSES.—V. Karapetoff. (*Journ. Am.I.E.E.*, March, 1929, V. 48, pp. 203–205.)

A mathematical theory is outlined explaining the general shape of corona cyclograms taken on a cathode-ray oscillograph.

SUR LE CALCUL DES MACHINES ÉLECTROSTATIQUES (The Calculation of Electrostatic Machines). —H. Chaumat. (*Comptes Rendus*, 22nd April, 1929, V. 188, pp. 1096–1098.)

The writer points out how vague are the ideas concerning, say, a Wimshurst machine compared with those about an alternator : "One may say that one multiplies an unknown quantity by an unknown factor." He indicates how such electrostatic machines should be dealt with, and shows the possibility of designing generators to give voltages varying with time according to laws hitherto untried—and possessing perhaps unexpected properties.

COMPARAISON ENTRE LES MACHINES ÉLECTROSTATIQUES ET LES MACHINES DYNAMO À COURANT CONTINU (Comparison between Static Electrical Machines and D.C. Dynamos).—H. Chaumat. (*Comptes Rendus*, 6th May, 1929, V. 188, pp. 1232–1234.)

A refutation of the idea (which "has certainly paralysed the efforts to develop static electrical generators") that these machines have such high internal resistance that the taking of any current from them must cause a quite inadmissible voltage-drop.

POWER FACTOR AND DIELECTRIC CONSTANT IN VISCOUS DIELECTRICS.—D. W. Kitchen. (*Journ. Am.I.E.E.*, April, 1929, V. 48, pp. 281–284.)

The peculiar temperature-variation of dielectric constant and power factor at different frequencies of rosin, rosin oil and castor oil, and the anomalous change in electric double refraction of rosin, are shown to be functions of the viscosity ; this influence of viscosity is explained on the Debye theory of dipole orientation.

ANOMALOUS CONDUCTION AS A CAUSE OF DIELECTRIC ABSORPTION.—J. B. Whitehead and R. H. Marvin. (*Journ. Am.I.E.E.*, March, 1929, V. 48, pp. 186–189.)

ABHÄNGIGKEIT DES WIDERSTANDES ISOLIERENDER UND ANDERER STOFFE VON DER SPANNUNG UND FREQUENZ UND IHRE FOLGEERSCHEINUNGEN : EXPERIMENTELLER NACHWEIS VON RAUMLADUNGEN (The Dependence of the Resistance of Insulating and other Materials on the Voltage and Frequency, and its Results : Experimental Proof of the Existence of Space Charges).—P. Böning. (*Zeitschr. f. tech. Phys.*, March and April, 1929, pp. 82–93 and 118–124.)

THE CHEMICAL ACTION OF ULTRASONIC RADIATION.—Schmitt, Johnson and Olson. (*Nature*, 30th March, 1929, V. 123, p. 506.)

Short notice of a paper in the February issue of the *Journ. of Am. Chem. Soc.*, on further experiments on this action.

LA STÉRILISATION DE L'EAU ET DES LIQUIDES PAR LES CIRCUITS EN METAL EN CONTACT DIRECT AVEC LE LIQUIDE (The Sterilisation of Water and other Liquids by Metal Circuits in direct Contact with the Liquid).—G. Lakhovsky. (*Comptes Rendus*, 15th April, 1929, V. 188, pp. 1069–1071.)

The bactericidal action of silver, described by Doerr in 1900, is explained by the writer as a purely physical effect due to the change of frequency (caused by contact with the mass of metal) in the "very high-frequency oscillations in the core of each cell or microbe." At any rate, the paper gives

definite records of the bactericidal property, which the metal loses after a certain amount of use. It can be restored, however, by a treatment which removes the deposits that insulate the microbe from contact with the metal. The white metal platonix produced the same results as silver.

EXPERIMENTS ON THE AMPLIFICATION AND DETECTION OF BIO-ELECTRIC CURRENTS BY MEANS OF THERMIONIC VALVES.—E. Benedetti. (*Nature*, 13th April, 1929, V. 123, p. 590.)

Short note on a Nat. Acad. Lincei (Rome) paper.

"TALKIES" IN THE HOME. (*Scient. Amer.*, April, 1929, p. 354.)

An American Corporation announces that it is ready to supply the public with a standard 16 mm. motion picture projector geared to a phonograph turn-table equipped with electric pick-up. A library service of films and their corresponding records is offered.

TALKING FILMS: NO. 3—THE TRI-ERGON SINGLE-UNIT PROCESS. (*Wireless World*, 10th April, 1929, V. 24, pp. 376–378.)

THE DETECTION OF FLAWS IN RAILS, USING VALVE AMPLIFIERS.—E. A. Sperry. (*Engineer*, 10th May, 1929, V. 147, p. 523.)

A description of the method now being practised by the Sperry Rail Service Corporation of Chicago, which detects flaws or defects representing as little as one-tenth of 1 per cent. of the area of the rail-head, and allows their size, characteristics and exact position to be located. It is equally applicable to non-ferrous metals. Energising (direct) current flows through the portion of the rail between two brushes (which pass over the rail at the rate of about five miles an hour). Midway between these main brushes come three searching brushes connected to the ends and the mid-point of the primary winding of an iron-cored transformer, the two halves of this primary being wound in opposition. The secondary is connected to a four-valve L.F. amplifier which controls a number of relays. One of these controls the release of a spray of paint which is ejected against the side of the rail whenever a defect is found; others control the recording pens and a check buzzer. In addition to its detecting capabilities the apparatus is claimed to have a definite advantageous effect on the rails owing to the magnetising effect of the electricity producing a release of internal strain and an ageing, seasoning and toughening of the metal without affecting its hardness.

MAGNETIC ANALYSIS.—R. L. Sandford. (*Journ. Am.I.E.E.*, January, 1929, V. 48, pp. 7–11.)

A survey of the methods of testing the mechanical characteristics, defects, etc., of ferrous metals, by observations on their magnetic behaviour. *See also* "Apparatus for Thermomagnetic Analysis," by the same author (*Bur. of Stds., J. of Res.*, April, 1929, No. 4, V. 2) illustrated by curves of typical results. "There are influences other than structural transformations which may lead to variations in magnetic characteristics, so that the data of thermomagnetic analysis should always be interpreted with caution. It appears, however, that this hitherto somewhat neglected method should be capable of yielding significant and valuable results."

CO-OPERATION IN SCIENCE AND INDUSTRY.—J. F. Thorpe. (*Nature*, 6th April, 1929, V. 123, pp. 531–533.) And, FINAL REPORT OF THE COMMITTEE ON INDUSTRY AND TRADE (*ibid.*, pp. 538–539.)

DIE BEDEUTUNG DER DRAHTLOSEN TELEGRAPHIE FÜR DIE WISSENSCHAFT (The Importance of Radio Telegraphy in Science).—J. Zenneck. (*Zeitschr. des V.D.I.*, 27th April, 1929, V. 73, pp. 565–573.)

German version of the paper dealt with in April Abstracts, pp. 207, 214 and 219.

RÜCKBLICK AUF DIE WICHTIGSTEN ARBEITEN AUF DEM GEBIETE DER ELEKTROTECHNIK IM JAHRE 1928 (A Survey of the Most Important Developments in Electrical Engineering in 1928).—(*E.T.Z.*, 28th March, 1929, pp. 477–486.)

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationary Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

THERMIONIC CATHODES.

(*Convention date* (*U.S.A.*), *28th October*, 1926. *No.* 279890.)

Valve filaments are made by depositing an oxide coating upon a core or carrier consisting of an alloy of cobalt and nickel and containing a third constituent which may be a ferro-compound of titanium, vanadium, silicon, or manganese added in sufficient quantity to render the alloy forgeable. This alloy replaces the use of platinum, iridium, and similar so-called noble metals, since it has no undesirable reaction with the emissive coating.

Patent issued to Westinghouse Electric & Manufacturing Co.

FREQUENCY MODULATION.

(*Convention date* (*U.S.A.*), *12th July*, 1927. *No.* 293803.)

In receiving signals transmitted in the form of a frequency-modulated carrier wave with constant amplitude, it is usual slightly to detune the receiving circuit and to depend upon the resonance characteristic to secure a quantitative response. The present invention consists in first heterodyning the incoming waves to obtain a frequency-modulated wave of intermediate frequency, which is then analysed by means of a detuned circuit to recover the original signal. In this way the side-band frequencies in telephony transmission can be reduced to a width of only 500 cycles.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

TOROIDAL COUPLING COILS.

(*Application date, 20th October*, 1927. *No.* 304622.)

A toroidal coil is threaded with a number of thin cylindrically wound coils which are moved around the periphery of the toroid so as to vary their mutual coupling. The annular coils may be made of different diameters so that they can be telescoped together to give a high coefficient of coupling.

Patent issued to W. S. Smith and N. W. McLachlan.

LOUD SPEAKERS.

(*Application date, 4th October*, 1927. *No.* 303470.)

The diaphragm is either plane or in the form of a smooth curve, and is substantially unthrottled. A fixed correcting-surface in the form of a plane disc or an annular ring is provided behind the diaphragm, the intervening air-space being adjusted to a critical depth so as to avoid damping. This is stated to eliminate inherent resonance and to give a straight-line response to all frequencies.

Patent issued to The Gramophone Co., Ltd., and A. M. Hallawell.

SOUND-REPRODUCERS.

(*Application dates, 30th January and 27th June*, 1928. *No.* 305429.)

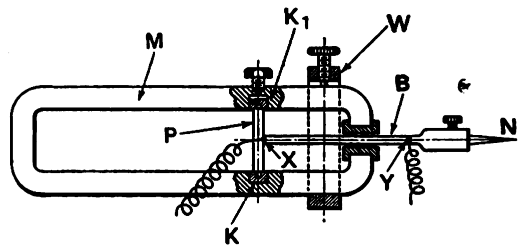
Relates to vibratory sound-reproducers of the kind in which the vibration is at least in part rotational about a real or virtual axis and in which the armature length in a direction perpendicular to the axis is at least as great as the distance of the nearer end of the armature from the axis. When the vibrator is in the form of a plain cantilever reed, as is commonly the case, difficulty is experienced in providing a sufficiently stiff reed which will not become overstressed even when vibrating at large amplitude. According to the invention that portion of the vibratory member which lies between the axis of rotation and the heel of the armature is made stiff, relatively to the armature, either by thickening the metal or by forming webs in it.

Patent issued to M. Trouton and Wireless Music, Ltd.

PICK-UP DEVICES.

(*Convention date* (*France*), *17th February*, 1927. *No.* 285454.)

A laminated blade *B*, carrying a record needle *N*, is mounted between the two poles of a permanent or electro-magnet *M* in such a way as to prevent any movement which is not strictly perpendicular to the lines of force across the pole-gap. This prevents any undesired currents due to parasitic



No. 285454.

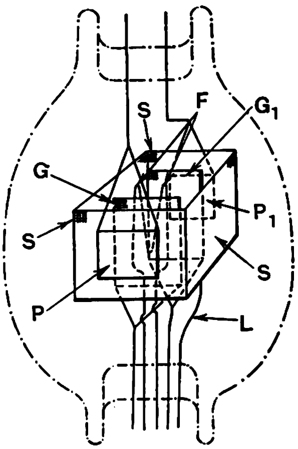
lateral movements of the blade. A pin *P* mounted in step bearings *K*, K_1 in the limbs of the magnet serves as pivot for the blade, pressure being adjusted by means of a screw at the bearing K_1. A screw-adjusted stirrup *W* regulates the width of the air-gap between the poles. The movement of the blade *B* is constrained in the stated manner by pads of rubber attached to each pole piece as shown. Vibration of the blade at right angles to the magnetic field induces corresponding currents which are collected by leads at the points *X*, *Y*, and fed to a pair of earphones, or to the input transformer of a low-frequency amplifier.

Patent issued to H. Hallam and J. R. M. Hélary.

PUSH-PULL S-G AMPLIFIERS.

(*Application date, 28th October*, 1927. *No.* 305251.)

At very high frequencies an undesirable capacity effect comes into evidence between the screening electrode and the plate. This gives rise to high-frequency currents which, flowing to earth through the impedance of the external circuits, create voltage variations and coupling between the screen and the grid. In order to prevent this residual capacity action, particularly in a valve intended for push-pull amplification, two control grids G, G_1 and plates P, P_1 are arranged symmetrically on each side of a central filament F, and the screening electrode S is formed as a box-like structure substantially surrounding both the grids and filament. A single lead L serves to bias the whole screen structure.



No. 305251.

Patent issued to C. S. Franklin.

PREVENTING FADING.

(*Convention date* (*U.S.A.*), *17th August*, 1927 *No.* 295693.)

To prevent fading effects the plane of polarisation of the waves emitted from a directional aerial system is continually varied. Three spaced directional aerials are inclined at different angles to the vertical, and are energised successively from a polyphase source or through suitable phase-regulating impedances. In addition the direction of the transmitted wave is varied slightly. The object is to secure a constant average field strength at the receiving point, in spite of varying reflection effects at the Heaviside layer.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

SCREENED-GRID VALVE CIRCUITS.

(*Application date, 20th October*, 1927. *No.* 304631.)

In order to reduce the damping of oscillatory circuits used in carrier-wave signalling, a screened-grid valve is adjusted to work as a "negative resistance" device. For instance it will operate on the downward slope of its characteristic curve by applying 100 volts to the screen, 6 volts to the control grid, and from 40–80 volts to the anode. A tuned circuit in the anode of the valve is then variably coupled to the oscillatory circuit in question.

Patent issued to W. S. Smith and N. W. McLachlan.

DIRECTION-FINDING BY OSCILLOGRAPH.

(*Application date, 3rd October*, 1927. *No.* 305250.)

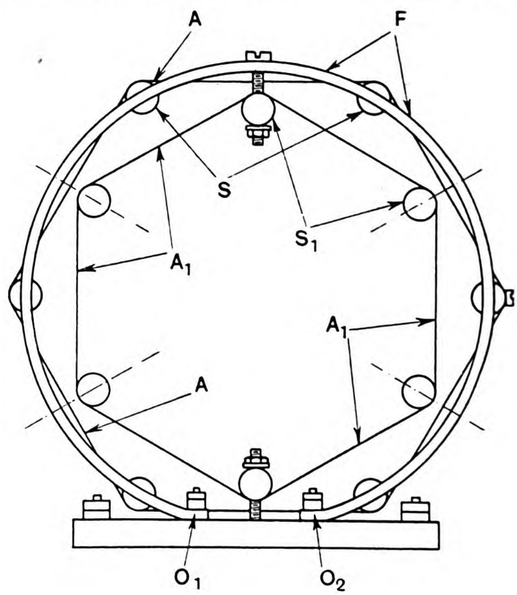
The direction of an incoming signal, or of a casual atmospheric disturbance, is determined by causing the voltages induced in a frame aerial to deflect the path of the ionic stream in a cathode-ray oscillograph. The pick-up voltages from a pair of crossed loop aerials are applied to two corresponding pairs of plates arranged at right angles on the outside surface of the oscillograph tube, and the resulting displacement of the ionic stream from normal indicates the direction of the incoming impulse. In order to remove the 180 degrees ambiguity in direction, the pick-up voltages from the frame aerials are combined with those received on an associated non-directional aerial.

Patent issued to R. A. Watson Watt and L. H. Bainbridge-Bell.

FRAME AERIALS.

(*Application date, 27th September*, 1927. *No.* 305109.)

The aerial wire A is wound over supports S fixed to a resilient or flexible frame F of substantially circular formation. The two metal rings forming the circular frame are broken at a suitable point, the ends O_1, O_2 being mounted on a base, with an intervening gap. The width of the gap determines the tension applied to the windings. A second series of windings A_1 may be strung over a number of draw bolts S_1 extending inside the circular frame. The base may be formed as a turn-table, the ends of the windings making a brushing contact with fixed terminals on the set.



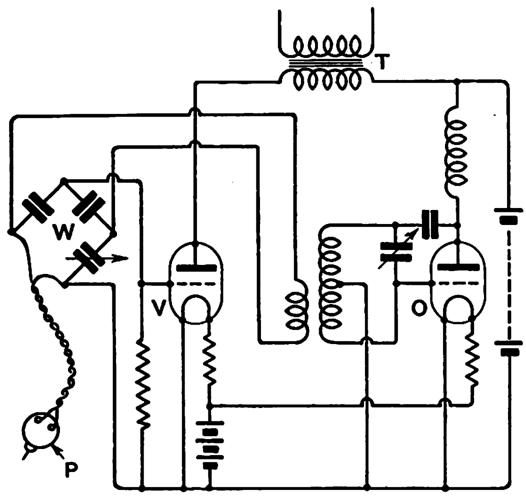
No. 305109.

Patent issued to B. Hesketh.

ELECTROSTATIC PICK-UPS.

(*Application date*, 29*th July*, 1927. *No*. 305052.)

When using an electrostatic type of pick-up for gramophone reproduction, the sensitivity of the arrangement is liable to be affected by the shunt capacity existing across the connecting leads. To remedy this defect, the pick-up *P* is connected in one arm of a balanced Wheatstone bridge *W*.



No. 305052.

Radio-frequency oscillations from a local generator *O* are fed across one diagonal of the bridge, the opposite diagonal being connected across the grid and filament of the input valve *V*, which functions mainly as a detector. As the pick-up moves across the record track, the bridge is unbalanced and modulated radio-frequency impulses are applied to the first valve, which rectifies them, and passes the output to a transformer *T* feeding one or more low-frequency amplifiers.

Patent issued to H. Andrewes and Dubilier Condenser Co., Ltd.

MAINS-SUPPLY UNITS.

(*Application date*, 19*th November*, 1927. *No*. 306436.)

The filaments are fed directly by *AC* current from the mains, whilst the plates are supplied with rectified current from the same source,the necessary components being housed together in one unit. Signal currents to be amplified are applied to a pair of push-pull valves, the filaments of which are supplied in parallel from one section of the secondary winding of the mains transformer. Another section of the secondary supplies heating current to the rectifier unit for the plate current. The plates of the two amplifiers are connected to opposite sides of the secondary winding of the transformer supplying high-tension voltage to the rectifier, so that any voltage variation due to the connection of one portion of the circuit to one point on the secondary is compensated for, and neutralised by, the symmetrical connection of the return path to the opposite side of the same winding.

Patent issued to C. Flanagan.

FREQUENCY-MODULATION SYSTEMS.

(*Convention date* (*U.S.A.*), 1*st September*. *No*. 296678.)

Under ideal conditions signals sent by frequency modulation should not be accompanied by any amplitude variation of the carrier-wave. In practice, however, such amplitude fluctuations are liable to occur, sometimes owing to fading and also to variations in the power input to the transmitter. Accordingly at the receiving end where the circuits are arranged to convert frequency changes into amplitude changes, the output contains the desired signals mixed with undesired amplitude components, and is correspondingly distorted.

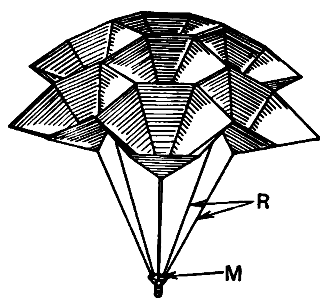
In order to cause the receiving circuits to respond to frequency modulation alone, and to be immune from undesired amplitude fluctuation, the incoming energy is applied co-phasially to two circuits having intersecting resonance curves with maximas lying on different sides of the operative band of signal frequencies. Frequency-modulated energy will then operate one or other of the circuits and so influence the common receiver, whilst amplitude variations are combined in opposition and are thus balanced out.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

LOUD SPEAKERS.

(*Application date* 28*th January*, 1928. *No*. 306263.)

A number of separate diaphragms are symmetrically arranged as shown in the Figure, and are vibrated by the same number of rods *R*, attached to and radiating from a single electromagnetic driving unit *M*. By dividing up the effective vibration surface in this way, a more efficient reproduction of the higher notes is secured since the central area of each separate diaphragm is brought into operation thus forming a total surface larger than that of the central area of a single large diaphragm vibrating under similar conditions. On the other hand, since the natural period of a bank of small equal-sized diaphragms is the same as that of anyone single diaphragm, "drumming" is avoided on the lower notes.



No. 306263.

Further, there is usually sufficient energy available in the driving unit to operate several large-diaphragm speakers, but since such an arrangement is impracticable, the present method allows such energy to be more fully and economically absorbed.

Patent issued to E. V. Mackintosh and C. French.

AUTOMATIC GAIN-REGULATION.

(*Convention date* (*Germany*), 31*st August*, 1927. *No.* 296397.)

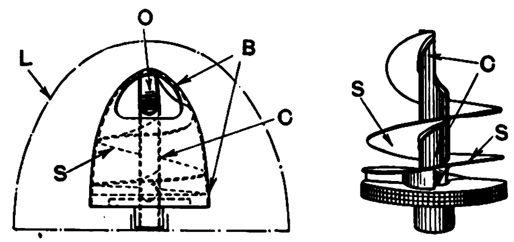
In a combined land-line and radio transmission system, the ether link is subject to "fading" and similar variable attenuation. In order to compensate automatically for this variable factor, it has been proposed to transmit a special "control" frequency, usually lying outside the band of signal frequencies, and to use this special frequency to adjust the grid potential of one or more of the amplifying valves on the receiving side. The present invention consists in distributing the rectified voltage derived from the incoming control frequency so as to adjust the operating grid potential of several of the amplifying stages instead of concentrating the gain control at one valve. This avoids any excessive movement of the operating grid potential and prevents any tendency to distortion or self-oscillation.

Patent issued to Siemens and Halske A-G.

LOUD SPEAKERS.

(*Application date*, 16*th November*, 1927. *No.* 305301.)

The horn is built up from a helical vane or strip *S* secured to a cone element *C*. A sleeve portion *B* fits closely over the helical vane, so that the channel formed between the vane and sleeve expands progressively according to a logarithmic law. An inverted dome or reflector *L* is placed over the combined unit as shown. Sound waves entering at the bottom of the sleeve travel along the exponential groove between the vane *S* and sleeve *B*, and enter the dome portion through an opening *O* at the top.



No. 305301.

Patent issued to M. Ward.

SOUND REPRODUCING DIAPHRAGMS.

(*Application date*, 21*st October*, 1927. *No.* 306193.

A disc or diaphragm for sound-reproducing instruments is made from wire gauze, or perforated plates, or interlaced strips of metal, coated with celluloid, ebonite, or wax. The coating solution may contain solid matter in solution, such as fine particles of wood. It is claimed that adequate reproduction of both high the low notes is ensured by the use of a metal diaphragm coated in this way.

Patent issued to W. A. Halden.

DIRECTIONAL AERIALS.

(*Application date*, 18*th November*, 1927. *No.* 305733.)

A directional aerial arrangement which is stated to give results comparable to the well-known "Beam" system, but is simpler and less costly to erect, consists of a number of vertical antennæ so spaced apart that the actual radiation resistance of the system as a whole is less than the radiation resistance of the separate antennæ considered in parallel. The spacing necessary to give this effect is from 0.5 to 0.68 of a wavelength, the optimum value being 0.57 wavelength.

Patent issued to T. L. Eckersley.

MULTIPLEX SIGNALLING SYSTEMS.

(*Application date* 9*th November*, 1927. *No.* 305703.

Where a single carrier-wave is modulated by a number of separate signal frequencies, such as by speech currents and one or more distinct Morse messages, difficulties arise in making the necessary tuning adjustments for heterodyne reception, owing partly to the extreme degree of accuracy to which the local oscillators must be adjusted and also to the necessity for maintaining the heterodyne frequencies in fixed relation so that the incoming signal frequencies may be kept centred on the band filter amplifiers. According to the invention the heterodyne frequencies are so arranged that, for correct reception, the same frequency is obtained at different parts of the multiplex receiver. This uniform frequency from different points is then fed into a common control circuit, and correct adjustment is ensured by the maintenance of a zero or no-beat effect in that circuit. A loud speaker or visible lamp relay may be utilised to indicate the presence of any undesired beat note in the control circuit.

Patent issued to G. A. Mathieu.

FREQUENCY MODULATION SYSTEMS.

(*Convention date* (*U.S.A.*), 18*th June*, 1927. *No.* 292469.)

In systems in which signalling is effected by changing the frequency of the carrier-wave, whilst maintaining its amplitude constant, the required frequency-variations are secured by short-circuiting an inductance coil shunted across a piezo-electric crystal, which acts as a master or drive oscillator anchoring the radiated waves about a mean frequency. The modulation changes in frequency so produced are abrupt and are not accompanied by any perceptible change in amplitude. The frequency variations are of the order of 0.1 per cent. of the fundamental crystal frequency. The systems permit of dual transmission, telegraphic signals being sent by means of a frequency change, whilst telephony signals are transmitted simultaneously by amplitude modulation. Provided the rate of Morse keying is kept high, no mutual interference between the messages occurs at the receiving end.

Patent issued to Westinghouse Electric and Manufacturing Co.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. AUGUST, 1929. No. 71.

Editorial.

The Definition of Selectivity.

IN an article in this issue Mr. Colebrook discusses this important subject. He distinguishes between selectivity and sharpness of tuning by applying the former term to the variation of response with variation of energising frequency, and the latter term to the variation of response with variation of some electric constant of the circuit. As he points out, it is doubtful if any simple definition of these terms could be formulated which would be applicable to such systems as band pass filters. Difficulties arise with even two tightly coupled circuits with their two resonant frequencies. If one confines one's attention to a simple resonant circuit the matter is relatively plain, and one is therefore somewhat surprised to find that, according to the definitions which he adopts, Mr. Colebrook comes to the conclusion that for current resonance in a simple circuit the selectivity is approximately twice the sharpness of tuning. On examination, however, it is seen that this is because of a definition which is quite arbitrary and of doubtful justification and not because of any essential difference in the quantities defined. If one defined the width as the distance across an object expressed in inches and the breadth as the same distance expressed in centimetres, one would obtain the result that the breadth of the object was 2.54 times its width. As Mr. Colebrook says in paragraph 11, "sharpness of tuning will be expressed in terms of the variable element of the network by means of which the tuning is obtained," but if the tuning is obtained by means of a variable condenser the question arises whether for the variable electric constant one should take the capacity or its square or its square root or some other function of it. The reader may be tempted to say that it is surely the capacity of the condenser which one alters, but this is not so; the root of the capacity is just as fundamental a quantity as the capacity itself, and we can just as well say that we are altering the former as the latter. We are dealing with resonant phenomena and, if one glances through Mr. Colebrook's formulæ, one will see that in such phenomena we are concerned with $\sqrt{C}$ rather than with C. We suggest that sharpness of tuning should therefore be expressed in terms of that property of the variable element which has a linear relation to the resonant frequency of the circuit, that is to say, $\sqrt{C}$ or $\sqrt{L}$ rather than a property like C or L, which has a more complex relation to the frequency. We think that if Mr. Colebrook modifies his suggestion along these lines, the highly undesirable anomaly of the selectivity being twice the sharpness of tuning will disappear.

G. W. O. H.

Measurement of Wavelengths of Broadcasting Stations.

An Account of the Work of the Brussels Checking Station of the U.I.R.

By R. Braillard and E. Divoire.

In a former article*, the authors explained to the readers of this journal the reasons why the application of the wavelength distribution plan, called "Plan de Genève," had imposed on broadcasting stations the absolute necessity for maintaining most strictly their nominal wavelengths with the greatest accuracy.

A wavemeter, or more exactly a frequency indicator, giving an accuracy of the order of one or two parts in 10,000 had been specially designed for this purpose by the Technical Commission of the International Broadcasting Union. The complete description of this instrument was the principal object of the above-mentioned article.

Since these wavemeters were taken into service, it has been found that it is not entirely sufficient to give each station an accurate and stable meter in order to ensure the success of the wavelength plan. In effect, the narrowness of the frequency band allowed to each station does not in principle permit of any error. Now, in spite of everything there are offenders ; on the one hand among adherents of the Union, it has happened that certain stations either are not supplied with so accurate a meter or that the maintenance engineer neglects for one reason or another to make use of it. On the other hand it is evident that the majority of the interferences are caused by those who do not adhere to the Union. These, even though they are only a small minority compared with the adherents, are however one of the principal causes of interferences which are heard in the reception of broadcasting.

Finally, in general, one finds that it is most useful to have a central organisation which can supervise all broadcasting stations and which can seek systematically the cause of interferences, the effects of heterodynes and other anomalies which may appear.

For these different reasons, the International Broadcasting Union decided to set up at the headquarters of its Technical Committee in Brussels a permanent listening and wavelength checking post. We propose to describe below the wavemeter which has been designed with this end in view.

Method of Measurement Adopted.

One had the choice between two methods of measuring wavelengths at a distance, both classic and well known ; the method of absorption and the beat method. After some preliminary tests we arrived at the conclusion that the first method, even though it presented, at least at first sight, more convenience and rapidity of operation, did not give the desired guarantees of precision when one was endeavouring to obtain an accuracy of the order of one part in 10,000.

The beat method was therefore adopted. Its principle is well known. The distant signal is received by means of a sensitive and selective receiver†, and is caused to interfere with a local oscillation produced by a heterodyne wavemeter calibrated to the desired accuracy. At the moment of the zero beat, the adjustment of the heterodyne wavemeter indicates the wavelength of the distant station under measurement.

It is easy to see that a number of precautions must be taken to ensure precision in such measurements. Among others it is evident that the error in calibration of the heterodyne wavemeter must be less than the maximum error allowed for the measure-

* "The Exact and Precise Measurement of the Wavelength of Transmitting Stations," *E.W. & W.E.*, June and July, 1927.

† The receiver used at the Brussels Control Station comprises two stages of high-frequency amplification using screened-grid valves, detector and two stages of resistance-coupled low-frequency amplification.

ment. The following procedure was adopted after one had become assured that the above conditions had largely been fulfilled :—

(1) To use a heterodyne wavemeter which was sufficiently stable for its calibration to remain non-variable during a certain time ; several days or more.

(2) To check the calibration of the apparatus as often as experience should show it to be necessary, by means of extremely accurate apparatus, relying on a primary standard of which the constancy was absolutely certain. This primary standard, in order to eliminate the errors which could result from unsuspected variation in the secondary standard, *i.e.*, the heterodyne wavemeter. But such a procedure, more exact in principle, would have had the inconvenience of making the operations much slower and much more laborious. Now among the qualities insisted on from the installation were ease and speed of operation, the apparatus eventually having to be put into the hands of operators but little skilled in laboratory measurements. On the other hand, practice having con-

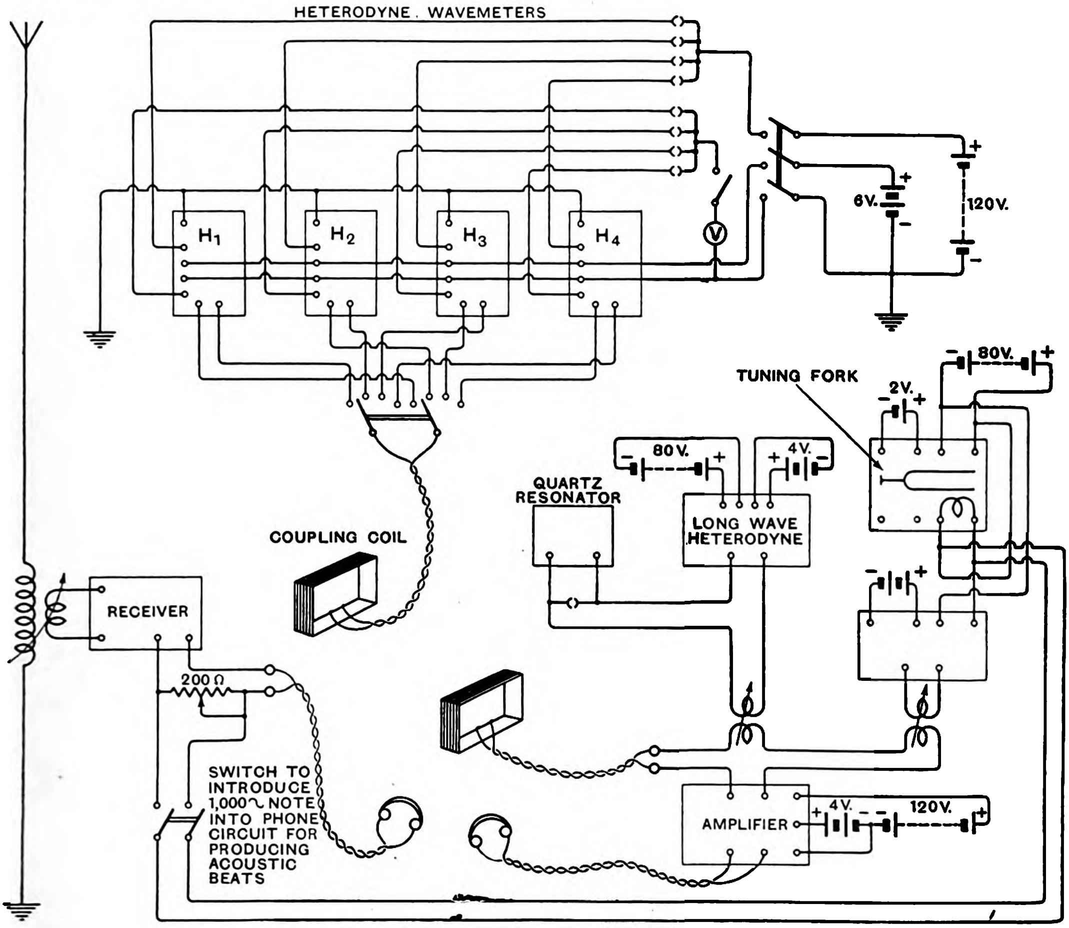


Fig. 1.—*General diagram of connections of the installation.*

standard in this case is the valve maintained tuning fork of special construction. It could here be objected that it would have been of interest to have been able to refer each measurement individually to the firmed that accuracy of the results obtained was more than sufficient for the needs of the moment, we confined ourselves to the above considerations.

We will now examine the result, the final

arrangement of which is given in Fig. 1 in a schematic diagram.

Description of the Heterodyne Wavemeter.

To achieve the first of the conditions specified above, the heterodyne wavemeter

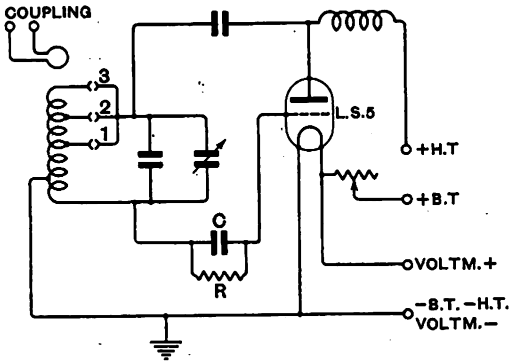


Fig. 2.—*Diagram of connections of the heterodyne wavemeter.*

must be robust and stable, which is assured by the constructional arrangements which we shall describe further on. Further, it should allow measurements of a transmission to be taken easily with an accuracy of the order of one part in 10,000. This condition exacting that the ranges should be sufficiently wide, one was led to foresee the necessity of a "battery" of 4 heterodyne wavemeters, of which each should have three ranges. The total of these 12 ranges cover the 1,000 kilohertz‡ approximately, of the band of frequencies allotted to broadcasting by the Washington Convention (200–545 metres).

To ensure robustness of the instrument, it is constructed on the same principles as were used in the wavemeter of the Technical Committee of the U.I.R. It is composed of particularly stable elements so as not to be susceptible to variations which may be caused by mechanical shock, etc. The metal construction is generally adopted, the volume of insulators being reduced as much as possible. The whole of the components, as well as the valve, are completely enclosed in an aluminium box which serves also as a screen.

‡ 1 kilohertz = 1 kilocycle per second. The term kilohertz, introduced by German professors, has been adopted by the Union Internationale de Radiodiffusion.

The diagram of connections is that of a Hartley circuit with parallel feed (Fig. 2). This circuit has the advantage of giving a fairly constant oscillating energy over a wide extent of frequencies. A plug and socket switch allows the use of three values of inductance. A one-turn coupling coil mounted inside the metal box provides for coupling to external circuits. The variable condenser is of the same type as that of the transmitter wavemeter above mentioned.

The variable condenser ensures, as has been said above, a range of about 100 kilohertz. To obtain ease of adjustment, the condenser is provided with a special slow-motion handle which also provides for insulation between the handle and the moving electrodes. (It should be noted that in effect the moving electrode is not at the potential of the chassis.)

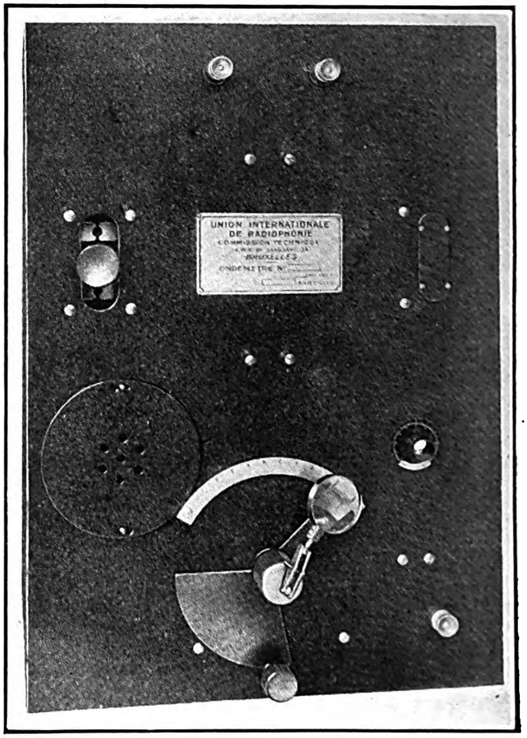


Fig. 3.—*Photograph of wavemeter panel.*

A vernier graduated from 1 to 10 is engraved on the pointer, which allows of reading to 1-10th of a degree or, after a little practice, to 1-20th of a degree. A lens

mounted on the pointer further assists reading (see Fig. 3).

The scale is divided into 100 degrees corresponding roughly to a range of 100 kilohertz. It follows, therefore, that the scale can be read to 50 hertz.§

A Marconi type LS5 valve is used. This is mounted inside the metal case with the other components, in order to avoid hand capacity effects. It should be mentioned that it was found essential to cover the end of the variable condenser spindle, which necessarily must project from the case, with a metal cap connected to the case. The battery connections are of lead-covered cable, of which the covering is connected to earth. The above-mentioned precautions have completely eliminated frequency variations due to the presence of the observer.

It is further necessary to guarantee the constancy of calibration against inevitable small variations due to changes in low-tension and high-tension battery voltages. It was possible to achieve this by a judicious choice on the one hand of the grid condenser *C* and of the grid leak *R*, and on the other hand of the L.T. and H.T. voltages. The value of condenser *C* is fixed at 0.005 mfd.; its value is not particularly critical. On the contrary the value of *R* is far from being uncritical.

The curves in Fig. 4 show :—

(*a*) The variation of the calibration of one of the heterodyne wavemeters, expressed in degrees of scale reading of the variable condenser, as a function of the low tension voltage for a high tension voltage of 120 volts.

(*b*) The variation of calibration as a function of the H.T. voltage for a L.T. voltage of 5 volts, the grid leak resistance being 20,000 ohms. (*c*) and (*d*) are similar curves for a grid leak resistance of 100,000 ohms.

Other values than these were tried, but they gave a far from ideal solution.

§ As a matter of fact, in order to conserve the same relative accuracy in reading over the whole band from 200–600 metres, it has been arranged to cover by each of the 12 ranges, a range of which the extent is proportional to the frequency of its middle point. It follows from the calculation of these ranges that throughout the whole extent of the band, one degree of the scale covers $\frac{12}{10,000}$ of the corresponding frequency at the point of graduation.

It will be seen from the curves that the most favourable values are :—

Grid leak resistance of 100,000 ohms.
Anode voltage .... 120 volts.
Filament voltage ...... 5 „

It should be noted that with these values, variations of calibration are too small to be evaluated in degrees of the condenser scale.

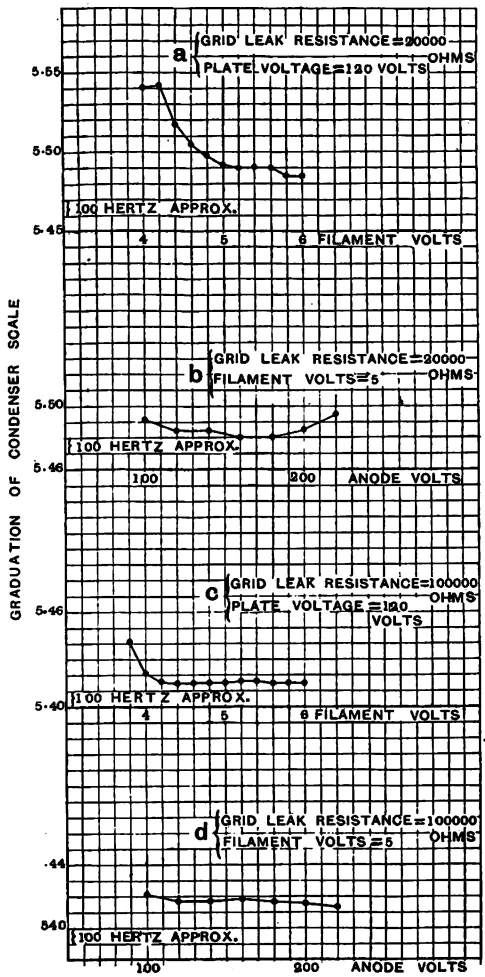


Fig. 4.—*Curves showing the variation of calibration of the heterodyne wavemeter as a function of low-tension and high-tension voltages for a grid leak resistance of* 20,000 *ohms and* 100,000 *ohms.*

The evaluations of differences in frequency were made by ear by listening to a beat between the wave emitted by the heterodyne wavemeter and that of the long wave hetero-

dyne (see Fig. 1), itself adjusted on to a harmonic of the multivibrator. These beats, even though they were of a very low frequency (of the order of 1 or 2 per second), could be easily appreciated due to the use of an auxiliary current of 1,000 hertz in the manner which we describe in detail further on. It was thus possible to be certain that the calibration did not vary by more than 2 parts in 100,000 for filament voltages between 4.5 and 5.5 volts.

It was further verified that with the values of components and voltages chosen as above, the energy output from the heterodyne wavemeter kept sufficiently constant over the whole extent of the three tuning ranges.

It was also established that the change in impedance of the circuit connected to the terminals of the coupling coil did not cause, by reaction, a change in calibration of the apparatus. It was found that the calibration did not change by more than one or two beats per second in changing over from the coupling turn being open circuited to it being connected to a coupling frame having about 10 turns such as that used in the layout shown in the diagram.

Lastly, desiring to make an estimate of the importance of slow changes in calibration which would result from deformation of the different components, due to changes in atmospheric conditions (temperature, etc.), and inevitable ageing of certain components, insulators, etc., the change in calibration was carefully recorded from day to day for certain particular frequencies.

Below in Fig. 5 will be found the curve showing the variation of calibration, and, as a reference, that of the change in temperature during a period extending from the 31st July to the 19th October, 1928. The frequency used for these observations was 966 kilohertz.

These variations are of the order of one in 10,000, and it is easy to take account of them by applying a correction factor to the measurements on a particular day.

Description of the Calibration Apparatus.

In order to realise the second of the conditions set forth at the beginning of this article, it is necessary to have apparatus which will check the calibration of the heterodyne wavemeters as often as is necessary. This operation should be rapidly and accurately performed.

The general layout shown in Fig. 1 was adopted.

Following a well-known arrangement already described in the article referred to above, the primary standard is a valve-maintained tuning fork which determines the fundamental frequency of a multivibrator. The harmonics of the latter are selected by zero beat method with the aid of a heterodyne called "long-wave heterodyne" in the figure (wavelengths from 1,000 to 3,000 metres approx., frequencies from 300,000 to 100,000 hertz). The harmonics of the latter in turn serve to calibrate the heterodyne wavemeters also by the zero beat method.

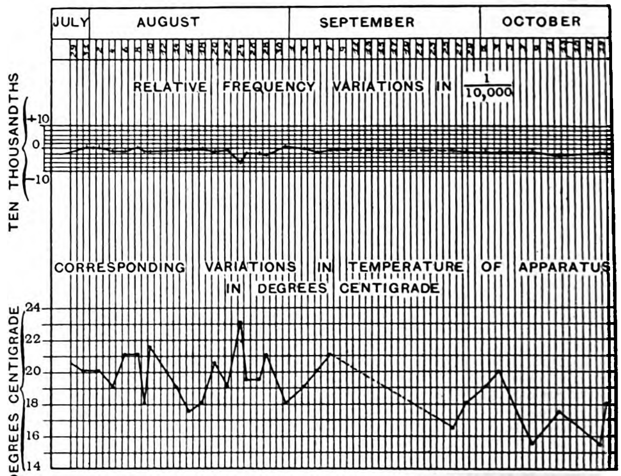


Fig. 5.—*Curves showing the variations in calibration of Range 2 of the heterodyne wavemeter No. 2, for a frequency of 966 kilohertz and variations in temperature.*

The appreciation of the zero beat in both cases is obtained by means of the amplifier shown.

It should be remarked that with constant practice it is often found possible to omit the intermediate operation ; that is to say it is possible to observe the beats between the heterodyne wavemeter and the higher harmonics (of the order of 600,000 to 1,000,000) of the multivibrator. Thus one cause of error is avoided.

The valve-maintained tuning fork made by

Messrs. Sullivan is of Elinvar, a special alloy of which the coefficient of elasticity varies very little with temperature. It was calibrated at the National Physical Laboratory, Teddington, under the direction of Dr. Dye to a frequency of 1,000 hertz with an accuracy of the order of one part in 100,000. The coefficient of variation with temperature is 0.000018 cycles per degree centigrade. (This can be taken into account if necessary.)*

The multivibrator is of the well-known type studied by Abraham and Bloch. The long-wave calibration heterodyne does not contain any special features except perhaps that its variable tuning condenser is provided with a slow-motion dial having a ratio of 1-400th in order that the zero beat point between it and the harmonics of the multivibrator can be found as easily as possible.

A luminous quartz resonator, calibrated specially by the Reichsanstalt at Berlin, is included in the apparatus in order to give a simple method of ascertaining which harmonic of the multivibrator is being used.

The amplifier consists of five stages, resistance coupled (2 high-frequency stages, a detector and two low-frequency stages). Transformer low-frequency amplification was avoided in order to get the best possible response to very low frequencies of the order of only a few cycles per second which are particularly necessary when adjustment to zero beat is being carried out.

Accuracy of Measurements.

The calibration of the heterodyne wavemeters can, with the aid of the installation described, be effected with an accuracy considerably greater than that which actual practice requires. The errors to be considered reduce themselves in effect to the following :—

(*a*) The error in calibration of the tuning fork, equal, as we have seen, to about one part in 100,000.

(*b*) The error in the appreciation of the zero beat between the harmonics of the multivibrator and the fundamental of the long-wave heterodyne. As it is possible easily to reduce this to a value less than one a second, the error is in any case less than one part in 100,000.

(*c*) The error in the appreciation of the zero beat between the harmonics of the multivibrator and the fundamental of the long-wave heterodyne. This is, as above, less than one part in 100,000.

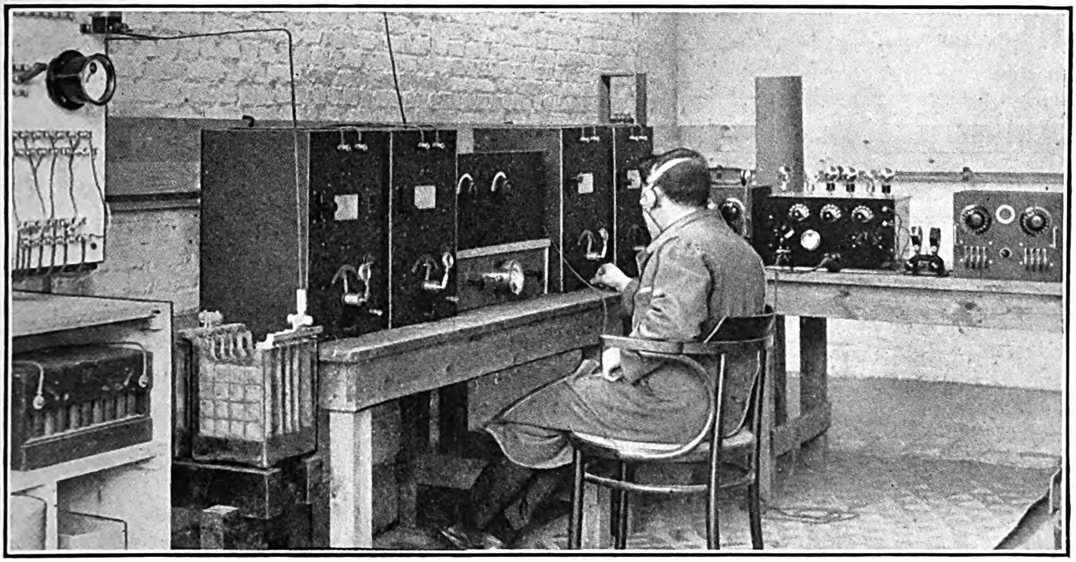


Fig. 6.—*A general view of the laboratory at the Brussels checking station.*

* Some measurements will be undertaken shortly, as a result of an agreement between the U.R.S.I., the Radio Research Board, the National Physical Laboratory and the British Broadcasting Corporation, in order to ascertain that the calibration of such forks does not vary even after a certain lapse of time (December, 1928).

It is to be noted that, as has been suggested above, one can, with certain practice, observe directly the beat between the fundamental of the heterodyne wavemeter and the harmonics of the multivibrator, and thus eliminate one of the preceding errors.

order of 1,000 cycles on one side of the silent point. It is easy to determine with great accuracy this note of 1,000 cycles by comparing it with the note given by the tuning fork. To this end the switch shown on the left at the bottom of Fig. 1 allows an alter-

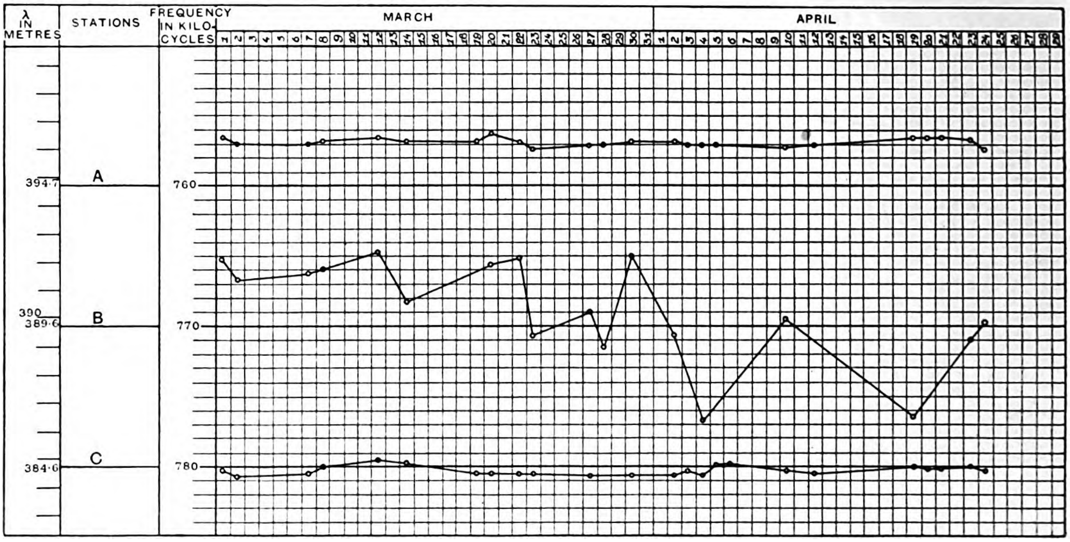


Fig. 7A.—*Summary of the measurements of transmissions taken on 3 stations during the months of March and April, 1928.*

(*d*) The error of reading the scale of the heterodyne wavemeter, which has been estimated above as one part in 10,000 as a maximum. This error, therefore, preponderates in comparison with the others and they can be, therefore, comparatively neglected.

Let us now evaluate the order of the accuracy which can be obtained in the measurements of broadcast transmitters.

This obviously must first take into account the error in the reading of the scale.

Secondly, the error in appreciating the zero beat with the received current which is under measurement must depend evidently on the intensity of this current. On an average it is found that the zero beat can be estimated to several parts in 100,000.

This error can, however, be reduced in the following way :—

Instead of finding the zero beat between the heterodyne wavemeter and the carrier to be measured, the heterodyne wavemeter is adjusted so as to obtain a beat note of the nating current of 1,000 hertz, produced by the tuning fork, to be introduced by means of a potentiometer into the telephone circuit of the receiver. The heterodyne wavemeter is then adjusted in order to obtain zero acoustical beat between the two musical notes. A similar procedure is then adopted for the 1,000 hertz beat note on the other side of the silent point on the heterodyne wavemeter.

Having thus determined the frequencies $f+1{,}000$ and $f-1{,}000$, the mean of the two readings gives with great accuracy the frequency f which it was required to measure. The error in such a measurement is in this way reduced to considerably less than one in 100,000.

It should be noted again that the reading of the scale gives the principal error.

In general then it can be estimated conservatively that the installation allows the measurement of the wavelengths with an accuracy of the order of one or two parts in 10,000 depending on the particular case.

The Use of the Apparatus.

Practice has shown that to obtain desired accuracy of results, it was prudent to check against the multivibrator one point on each of the 12 ranges each day; thus 12 correction factors are obtained. With a little practice this operation could be carried out very quickly.

The heterodyne wavemeters have shown themselves to be easily handled, and it is possible for operators not having great skill in laboratory measurements to carry out accurate measurements without difficulty.

At the Brussels Checking Station between 100 and 150 measurements are made daily during a period of about four hours' listening. The accuracy of these measurements makes it possible to follow very closely the fluctuation in the wavelength of certain stations which have shown variations in frequency.

Fig. 7A shows, as an example, a curve giving the day-to-day variation of a station *B*, having stations *A* and *C* on either side of it. One sees how station *A*, in order to keep clear of the variations of *B*, has been obliged to adopt a frequency of approximately 757 kilohertz instead of staying on the frequency nominally assigned to it.

Following intervention by the Brussels checking station, *B* took steps to maintain a constant frequency. The resulting curve in Fig. 7B shows that the efforts made were entirely successful.

Measurement of Scintillation or Variation in the Frequency Due to Modulation (Frequency Modulation).

The method of measurement which makes use of auxiliary low-frequency current described above, has made it possible to observe very simply an annoying phenomenon met with in radio telephony transmitters, and one which it is not always easy for technicians to eliminate. This rapid and irregular variation of carrier frequency, due to modulation of the carrier wave by speech or music, can be compared to a sort of scintillation. The principle of measurement is the following:—

One arranges for an approximately 1,000-hertz beat note between the wave to be observed and the heterodyne wavemeter.

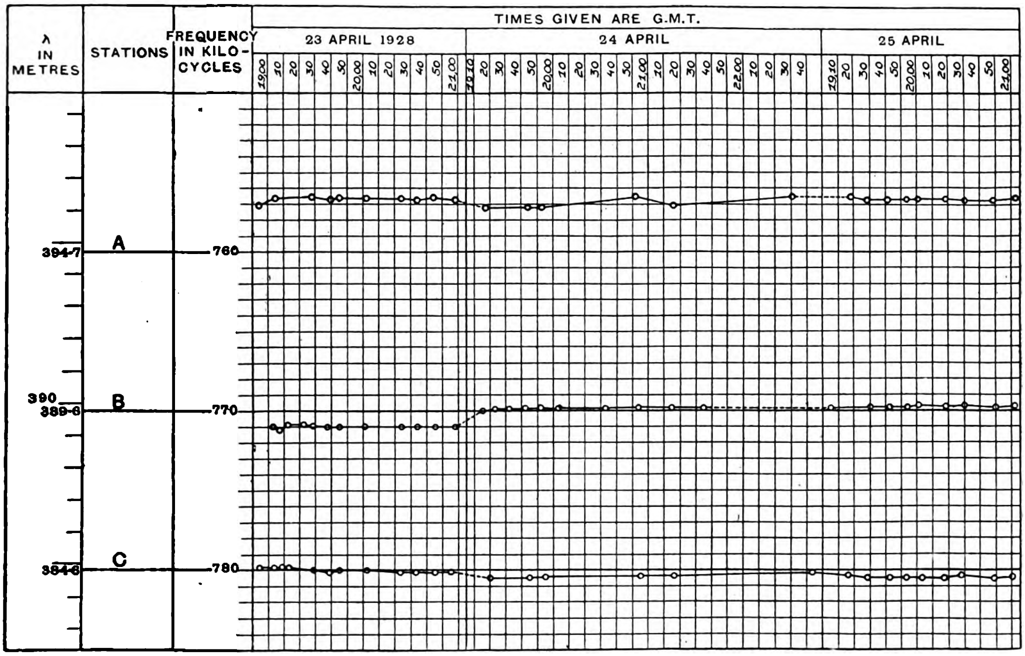


Fig. 7B.—*Summary of measurements for the same stations on the 23rd, 24th and 25th April, after intervention by the Technical Committee.*

This note of approximately 1,000 hertz is caused to beat with the low-frequency note of 1,000 hertz given by the valve-maintained tuning fork as described above.

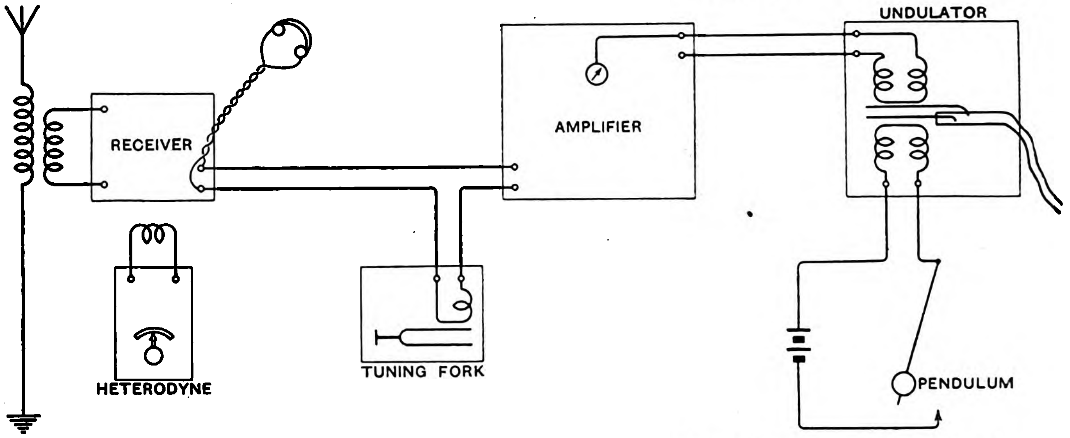


Fig. 8.—*Diagram of connections of the apparatus for recording scintillation* (*frequency modulation*).

A very low frequency beat is thus obtained, which on this occasion is not reduced to zero, but by a suitable adjustment of the heterodyne wavemeter is arranged to have a value of a few cycles per second. The frequency of the tuning fork being constant, the frequency of the low-frequency beat depends on the value of the beat note between the heterodyne wavemeter and the carrier wave. This latter beat note in its turn depends only on the frequency of the carrier wave, for the calibration of the heterodyne wavemeter remains perfectly constant, in any case during a limited time, thanks to the precautions taken and described above.

Thus by the double-beat method, scintillation (frequency modulation) of a station can be appreciated.

In order to record this very low frequency second beat note at the output of the receiver, it is rectified and amplified by a suitable amplifier for dealing with such low frequencies (see Fig. 8), and connected to a recorder.

The beats of a seconds pendulum are recorded simultaneously on the tape by means of an auxiliary inker.

Fig. 9 shows examples of curves taken by means of this arrangement. It should be noted that stations whose transmission can be registered in such a way are among the better ones. Many stations, however, produce such a marked amount of frequency modulation, that it would not be possible to record on a tape even with the aid of an undulator of very rapid movement, the beats varying from 0 to several hundreds per second.

There is no doubt that such stations occupy a gamut in the band of frequencies allotted to broadcasting much larger than that to which they would normally have a right, and they produce much more serious jamming than one would imagine.

Organisation of Measurements.

The Radio-electric Conference at Prague has entrusted the Belgian Administration with the measurement of the wavelengths of broadcasting stations.

This Administration, in acknowledging the technique and the impartiality of the members of the Technical Commission who have made these measurements for more than two years, has asked the Checking Centre at Brussels to continue its work on an official basis.

The results of the daily measurements of the Checking Centre are sent monthly to the different European administrations through the intermediary of the Belgian Telegraph Administration and the International Telegraph Bureau at Berne.

Besides the Brussels checking station, the Technical Commission of the International Union of Broadcasters has, at the moment, the benefit of the results of measurements taken at the checking stations of

the B.B.C. (Keston) and the Reichspostzentralamt, Berlin.

Keston is equipped with apparatus in all ways similar to that at Brussels ; Berlin uses apparatus specially designed by the technical *personnel* of the Reichspostzentralamt.† Specially organised tests have established the close agreement existing between the several centres in the matter of absolute values of frequency standards. It was particularly useful to be certain of such agreement before conducting the accurate measurements considered indispensable by the Technical Committee.

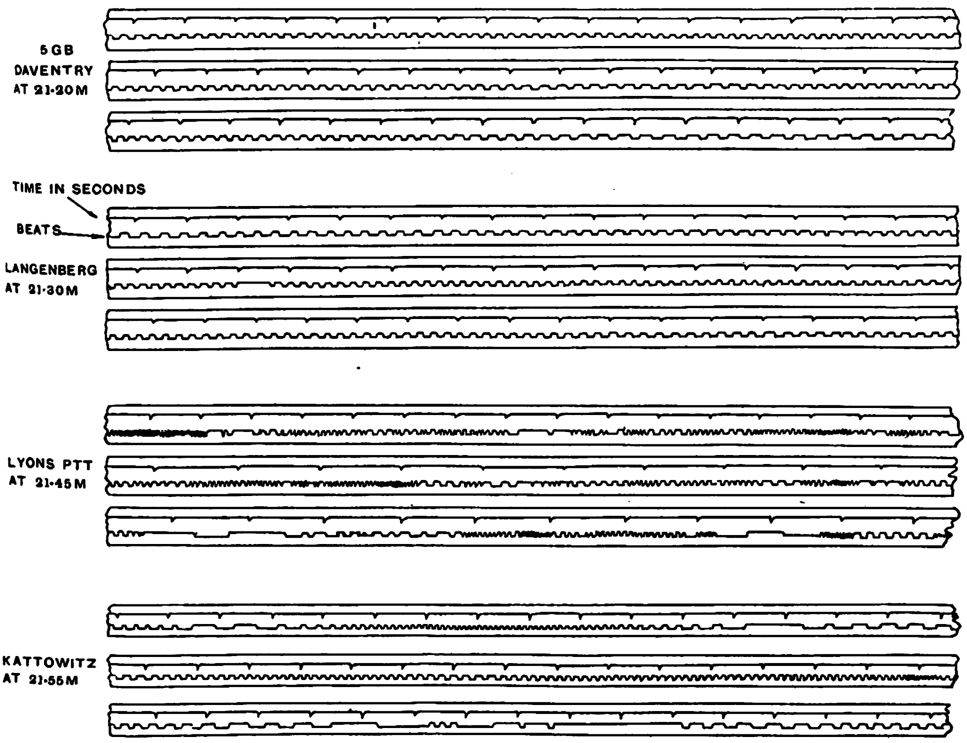


Fig. 9.—*Examples of scintillation records for 4 different stations.*

The three centres exchange the results of their measurements several times a week. Further, it has been found that practically all cases of jamming can be spotted by one or other of these centres. In this manner a close collaboration has been established of which the results appear more and more indispensable. The case represented in Fig. 5 is an example.

There is no doubt that the extension of such methods of control to transmitters in other categories of radioelectric services should be seriously considered from now on.

Although finding itself a relative newcomer in the domain of radio electricity, broadcasting has pointed the way to its seniors in this as in many other directions.

Let us confess, however, that it has been forced to do so by an overwhelming necessity to safeguard its own existence.

But the insistent development of radio communication, the progressive invasion of the whole spectrum of frequencies cannot but result sooner or later in placing other branches of radio in a similar situation. Following the Washington Convention, others more severe will follow, and checking apparatus such as that which we have just described will cease to appear in the eyes of some as a superfluous luxury, but will become, on the contrary, an indispensable auxiliary to a well-conducted service.

† Prague (Radiojournal) will very shortly open an installation of the same model as that at Brussels, and models using identical apparatus are in construction for future centres at Paris, Madrid and Stockholm.

The Definition of Selectivity.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

SELECTIVITY is a very important circuit characteristic. There is, however, no universally accepted definition of this term, which is capable of general application to all cases of electrical resonance. Such terms and formulæ as are at present in use have been derived from the theory of the simple series resonant circuit, and are not in a form which makes clear their application to some of the more complex types of resonance which are utilised in wireless practice.

2. Existing terms do not sufficiently clearly distinguish between selectivity, which refers to the variation of the behaviour of a given circuit or network with respect to frequency, and another characteristic which, for want of a better name, can be described as "sharpness of tuning." The latter refers to the variation of the behaviour of the circuit with respect to a variation of some specified element of the circuit, the frequency being kept constant. The behaviour with respect to the variation of a tuning condenser is an example of this.

(In circular No. 74 of the Bureau of Standards, this latter characteristic, *i.e.*, "sharpness of tuning," is described in relation to a simple series resonant circuit and is called alternatively "selectivity" and "sharpness of resonance." In the writer's opinion, however, it is preferable to confine the term "selectivity" to the behaviour of the circuit with respect to frequency variation, since the term suggests the selective behaviour of the circuit with respect to electromotive forces of various frequencies. The term "sharpness of resonance" is not quite suitable, since resonance can be obtained in two ways, either by a variation of the frequency of an applied electromotive force, or by variation of circuit elements, the applied frequency remaining constant. The term "sharpness of resonance" could be applied equally well to either of these, whereas the proposed term "sharpness of tuning" is quite specific).

3. Both "selectivity" and "sharpness of tuning" are circuit properties, depending only on the electrical constants of the circuit or net work and on the frequency. It is very desirable, however, that these characteristics should be so defined as to take account of the fact that any given network may be associated with a number of different types of resonance. Thus, for instance, in the case of a simple series resonant circuit there will be a current resonance, associated with certain frequency or circuit conditions. The current maximum, however, will not exactly coincide with the maximum potential difference across the inductance with its associated resistance which will occur at a slightly different frequency. Each of these two resonances will have slightly differing selectivities. In the case quoted the differences will in general be negligibly small, but this will not necessarily be so in all cases.

For a complicated network there will obviously be a large number of alternative resonances, depending on the actual electrical quantity concerned. This latter may be any one of a number of branch currents, or the potential difference across any desired component impedance or impedance group. Any definitions of selectivity or sharpness of tuning should therefore be framed in such a way as to take account of these possibilities.

4. For many simple cases there will be a comparatively simple relation between the selectivity and the sharpness of tuning of any given resonance. In fact, assuming for the moment the definitions of these quantities to be as suggested below, the former, in most simple cases (such as that of the series resonant circuit) will be very approximately twice the latter. It should be clearly realised, however, that in a number of cases of considerable practical importance there will be no such simple relationship. Consider, for instance, a network consisting of a condenser-tuned receiving circuit associated with any amplifier having tuned-anode circuits. Taking the resonance of some suitable output quantity, such as the potential difference across the anode impedance of the last valve, then the

sharpness of tuning of the input circuit will not involve the characteristics of the tuned-anode circuits, since the input frequency remains constant. The selectivity of the whole receiving system will, however, be a totally different quantity, since it will involve the selectivities of all the intermediate circuits. From the point of view of the elimination of interference, the latter will, of course, be the important characteristic.

5. The following proposals are put forward only as a basis for a discussion of the most suitable definitions of selectivity and sharpness of tuning. As a preliminary it will be necessary to consider the term resonance and to define it in a manner which will give a wide generality to its application.

6. Given a certain network of conductors of any character, let A and B be any two simple harmonic alternating electrical quantities of frequency $\omega/2\pi$, the amplitudes $\hat{A}$ and $\hat{B}$ of which are related by an equation

$$\hat{B} = \frac{\hat{A}}{Z}$$

where Z is a function of ω and of the electrical constants of the network. The quantity Z may thus be regarded as a form of generalised impedance connecting the quantity $\hat{A}$ which might be, for example, an electromotive force, with the quantity $\hat{B}$ which might be, say, the current in some particular branch of the network.

7. In general there will be a certain value or values of ω for which Z has a critical value, which may be a maximum or a minimum. This condition can be described as a resonance of Z (or as a resonance of B with respect to A). If ω_r be any such value of ω the critical or resonant condition is specified by

$$\frac{\partial Z}{\partial \omega_r} = 0 \quad \frac{\partial^2 Z}{\partial \omega_r^2} \neq 0$$

(Z_r will, of course, be a maximum or minimum according as $\partial^2 Z/\partial\omega_r^2$ is negative or positive).

8. The state of resonance being defined by the vanishing of the first differential coefficient, the magnitude of the second would seem to be an appropriate basis for specifying the sharpness of the critical condition, but it should be embodied in a form which involves the ideas of proportional changes of frequency ($\delta\omega/\omega$) and corresponding proportional changes in Z (just as in the analogous case of resolving power in optics, which is expressed in terms of $\delta\lambda/\lambda$).

9. A formulation consistent with the above and consistent with existing ideas on selectivity in the usual simple cases is

$$\text{selectivity} = \omega_r\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial \omega_r^2}\right|}$$

(the vertical strokes meaning "magnitude of.")

10. The physical significance of this formula is made clearer by the following :—

$$\omega_r\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial \omega_r^2}\right|} = \left(\underset{\delta\omega\to 0}{lt.}\sqrt{\frac{\delta(Z^2)}{Z^2}\Big/\frac{\delta\omega}{\omega}}\right)'_{\omega=\omega_r}$$

Of these equivalent formulations that on the left is clearly the form for analytical purposes and that on the right for measurement with R.M.S. measuring instruments.

11. The definition of sharpness of tuning will be identical in form with that of selectivity but will be expressed in terms of the variable element of the network, whatever this may be, by means of which the tuning is obtained. Thus, for example, if the variable element be a condenser of capacity C, the resonant condition is defined by

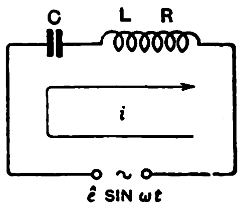
$$\frac{\partial Z}{\partial C_r} = 0 \quad \frac{\partial^2 Z}{\partial C_r^2} \neq 0$$

and

$$\text{sharpness of tuning} = C_r\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial C_r^2}\right|}$$

12. Applications of the above definitions to typical cases are given in an appendix.

13. *Limitations.* The above definitions are probably not applicable to certain types of filter circuit or to combinations of tuned circuits designed so as to have virtually a square topped resonance curve. It is doubtful whether any simple numerical specification could be drawn up which would be usefully applicable both to normal types of resonance and to the special characteristics of band-pass filters and similar circuit combinations.



APPENDIX.

Deduction of selectivity and sharpness of tuning in some typical cases.

1. *Simple series resonant circuit.*

1.1. *Current resonance.*

Putting $\hat{\imath} = \hat{e}/Z$

$$Z^2 = R^2 + (\omega L - 1/\omega C)^2$$

1.1.1. Selectivity, *i.e.* L, C and R constant, ω variable.

$$2Z\frac{\partial Z}{\partial \omega} = 2(\omega L - 1/\omega C)\ (L + 1/\omega^2 C)$$

$$= 0 \text{ when } \omega L = 1/\omega C.$$

i.e., $\omega_r = 1\sqrt{LC}.$

$$\frac{\partial^2 Z}{\partial \omega_r^2} = \frac{4L^2}{R} \text{ and } Z_r = R.$$

Therefore

$$\text{Selectivity} = \omega_r\sqrt{\frac{1}{Z_r}\left|\frac{\delta^2 Z}{\delta \omega_r^2}\right|}$$

$$= 2\sqrt{\frac{L}{CR^2}}.$$

1.1.2. Sharpness of tuning (condenser variation).

In this case ω, L and R are constant and C variable:

$$2Z\frac{\partial Z}{\partial C} = \frac{2(\omega L - 1/\omega C)}{\omega C^2}.$$

Therefore

$$C_r = 1/\omega^2 L \text{ and } Z_r = R$$

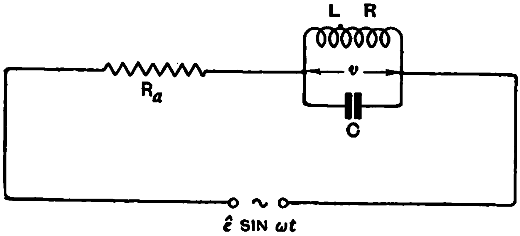
$$\frac{\partial^2 Z}{\partial C_r^2} = \frac{\omega^6 L^4}{R}.$$

Therefore

$$\text{Sharpness of tuning} = C_r\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial C_r^2}\right|}$$

$$= \frac{1}{\omega^2 L}\sqrt{\frac{1}{R}\,\frac{\omega^6 L^4}{R}}$$

$$= \frac{\omega L}{R}\left(= \sqrt{\frac{L}{C_r R^2}}\right).$$



1.2. Resonance of potential difference across the condenser.

$$\hat{v} = \frac{\hat{e}}{\omega C\sqrt{R^2 + (\omega L - 1/\omega C)^2}}$$

i.e., $Z^2 = \omega^2 C^2 R^2 + (\omega^2 LC - 1)^2$

1.2.1. Selectivity

$$\omega_r^2 = \frac{1}{LC}\left(1 - \frac{1}{2}\,\frac{CR^2}{L}\right)$$

$$Z_r^2 = \frac{CR^2}{L}\left(1 - \frac{1}{4}\,\frac{CR^2}{L}\right)$$

$$\frac{\partial^2 Z}{\partial \omega_r^2} = \frac{4LC}{Z_r}\left(1 - \frac{1}{4}\,\frac{CR^2}{4L}\right)$$

This gives

$$\text{Selectivity} = \frac{2\omega_r L}{R} = 2\sqrt{\frac{L}{CR^2}}\sqrt{1 - \frac{1}{2}\,\frac{CR^2}{L}}$$

Note that ω_r is not quite the same for current and potential resonance.

1.2.2. Sharpness of tuning.

$$C_r = \frac{L}{R^2 + \omega^2 L^2}$$

$$Z_r^2 = \frac{R^2}{R^2 + \omega^2 L^2}$$

$$\frac{\partial^2 Z}{\partial C_r^2} = \frac{\omega^2}{Z_r}(R^2 + \omega^2 L^2)$$

Therefore

$$\text{Sharpness of tuning} = \frac{\omega L}{R} = \sqrt{\frac{L}{C_r R^2} - 1}.$$

2. Another interesting case is that shown in the second Figure, which is an approximation to a tuned anode amplifying circuit.

The resonance to be considered is

$$\hat{v} = \hat{e}/Z$$

The analysis is somewhat lengthy, but can be summarised as follows :—

$$Z^2 = \frac{(R_a + R_0)^2 + X_0^2}{R_0^2 + X_0^2}$$

where

$$R_0 = \frac{R}{(1 - \omega^2 LC)^2 + \omega^2 C^2 R^2}$$

$$X_0 = \frac{\omega L(1 - \omega^2 LC) - \omega CR^2}{(1 - \omega^2 LC)^2 + \omega^2 C^2 R^2}$$

2.1. *Selectivity.*

$$\omega_r^2 = \frac{1}{LC}\left\{-\frac{CR^2}{L} + \left(1 + 2\frac{CR^2}{L} - \frac{4R}{R_a}\right)^{\frac{1}{2}}\right\}$$

$$= \frac{1}{LC}\left(1 - \frac{2R}{R_a}\right) \text{ very approximately.}$$

$$\approx \frac{1}{LC} \text{ if } R << R_a.$$

For the approximation $\omega_r^2 = 1/LC$.

$$\text{Selectivity} = \frac{2\omega_r L}{R}\left(\frac{R_a}{R_a + \frac{\omega_r^2 L^2}{R}}\right)$$

$$= 2\sqrt{\frac{L}{CR^2}}\left(\frac{R_a}{R_a + L/CR}\right)$$

2.2. Sharpness of tuning.

$$C_r = \frac{L}{R^2 + \omega^2 L^2}$$

and Sharpness of tuning

$$= \frac{\omega L}{R}\left(\frac{R_a}{R_a + \frac{R^2 + \omega^2 L^2}{R}}\right)$$

(The formulæ in this case are exact and not approximate.)

Reduction of Distortion in Anode Rectification.

By A. G. Warren, M.Sc., M.I.E.E., F.Inst.P.

SUMMARY.

It is suggested that, although in modern speakers the frequency response is by no means perfect, the more serious distortion which still persists is due to the presence in the reproduction of alien tones (enharmonic and harmonic). Alien harmonics tend to render the reproduction unduly "stringy," and it is with methods of suppressing them that this article is particularly concerned. In a well-designed set such false harmonics are introduced chiefly during the process of rectification. The general principles of anode rectification are treated and it is shown that the distortion is reduced considerably by increasing the value of the grid swing applied to the rectifier until the sensitivity attains a practically constant value. Although grid swings (peak value) of 2 or 3 volts are commonly advocated it is shown that they are quite inadequate to produce any marked improvement. In treating the theory of rectification it is commonly assumed that a parabolic relation exists between the applied and rectified voltages and it is asserted that, in consequence, distortion is reduced by increase of grid swing. It is shown that this argument is fallacious and that, so long as the relation remains parabolic (which it practically does over the extent of grid swings usually employed), the distortion is unaffected by the magnitude of the grid swing. Fortunately when larger grid swings are used the relation between the applied and rectified potentials deviates considerably from the parabolic form and the reduction of rectification distortion becomes possible. To secure freedom from false harmonics a peak value of grid swing of the order of 10 volts must be employed giving (with an average valve) an L.F. output of about 7 volts. A valve so used gives almost perfect rectification. The subsequent low frequency amplification must be less than that usually adopted. The application of the principles suggested to secure purer reproduction involves a transference of part of the process of amplification from the post-detector to the ante-detector stages.

1. Introduction.

The last two or three years have witnessed enormous strides in the quality of reproduction of broadcast music. Much of the improvement may be directly attributed to the adoption of speakers, such as the "moving-coil," which are capable of reproducing a more comprehensive range of the musical scale. But this, in itself, can account for but a fraction of the advance that has taken place. The output of a modern speaker can be accurately described as a *reproduction*, admittedly imperfect, of the original performance; it has outgrown the stage of music *as played by the loud speaker*. To what is this improvement due? It cannot be attributed solely to the better response to the gamut of musical frequencies; many gramophones, whilst failing to approach the reproduction of a good loud speaker, have a more uniform frequency response. The author would attribute it to the fact that alien sounds have been greatly reduced. A closer approach to the original performance has permitted the faults and the inadequacies of the reproduction to be recognised; recognition has resulted in progress towards correction.

Distortion in reproduction is of three main types:—

(a) *Variation of sensitiveness of the system (speaker or set) to notes of different frequencies.* This is usually manifested by an inadequate reproduction of both the bass and notes of high frequency. Though the effect is much less noticeable with a moving coil speaker than with the earlier diaphragm-horn types, the response is still far from uniform (see McLachlan, *Wireless World*, March 20th, 1927, p. 373). Given, however, some approach to uniformity of response, an approximation to realism of reproduction is possible. A consideration of the conditions obtaining in a concert hall suggests that the quality must change considerably according to the position of the listener; due to reflections and interference the relative intensities of notes of different frequencies must vary greatly from place to place, but the sense of realism is not lost. It appears unnecessary to insist upon too rigid a uniformity of sensitiveness to different

frequencies. Though it used to be suggested that the reassembly of all frequencies in their correct proportions would result in perfect reproduction, it must be recognised that this condition overlooks the possibility of types of distortion which may be even more serious.

(b) *The introduction of alien harmonics.* The differences of quality between notes of the same pitch, as produced by various instruments, can be attributed to the differences in relative intensity of the various harmonics present. If the relative intensities are preserved, reproduction is natural. Though the quality must suffer through the changing sensitiveness of the speaker to various frequencies, more serious distortion may result through the introduction of *alien* harmonics. Their cause is treated more fully later.

(c) *The introduction of alien (enharmonic) tones.* A receiving set or speaker always possesses various possible modes of oscillation—electrical or mechanical. Such modes tend to produce resonance of particular frequencies—the reproduction of certain notes with undue prominence. An effect which may be more distressing is the tendency to the production of transient discordant oscillations, set up particularly in staccato passages or with percussion instruments (see McLachlan, *Wireless World*, 10th October, 1928, p. 497, and 17th October, 1928, p. 539). Such alien tones together with alien harmonics are mainly responsible for "colouration" (loud speaker or gramophone tone).

2. Distortion in the Set.

It is a tribute to the progress which has been made in the speaker itself that each improvement in the set is accompanied by a noticeable improvement in the reproduction. The set has to perform two functions: (*a*) amplification; (*b*) rectification—or the separation of the modulation from its high frequency carrier. For a given frequency no appreciable distortion need occur in amplification so long as the valves are worked well within the straight portions of their characteristics—design must be liberal. The high frequency stages must be designed so that amplification is sensibly constant over a range of 5,000 p.p.s. above and below the frequency of the carrier wave; it is not proposed to consider that problem here, though its practical solution is not difficult. Deviations from rectilinearity of the amplification in the low frequency stages introduce alien harmonics, but this trouble should not arise here. The case is different, however, with rectification. It is commonly acknowledged that rectification introduces distortion, which may sometimes be very considerable, though, under good conditions, particularly with anode rectification, a very fair approach to pure reproduction may be attained. It is well known that the sensitiveness of anode rectification is poor when the signal voltage applied to the grid of the detector is small, and it is generally maintained that with increase of grid voltage not only does the sensitiveness increase but the quality also improves. This is often the case, but the improvement in quality referred to is rarely directly due to the reduction of distortion in rectification. The improvement is usually most noticeable when provision has been made for an increase in high-frequency amplification, ostensibly for the purpose of increasing the efficiency of rectification. The necessity for super-sharp tuning is thereby removed and the higher notes, previously very deficient, begin to reveal themselves. High-frequency circuits too sharply tuned may cause bad distortion. Rectification distortion is quite different and consists in the addition to the output of alien harmonics which are not present in the modulated input. Such harmonics produce an unnatural "stringiness" of tone; their reduction is accompanied by a very noticeable approach to natural reproduction.

The reduction of rectification distortion cannot be accomplished by the use of input grid potentials of the magnitudes usually advocated, 1 or 2 volts R.M.S. Over such a range the distortion is almost constant; often there is a tendency for the distortion to increase slightly with growth of the alternating grid potential. It is shown later, however, that with a properly chosen value of the grid bias it is possible to reduce the distortion almost to the vanishing point by the application of grid potentials much in excess of those usually contemplated.

3. General Principles of Anode Rectification.

Fig. 1 represents the usual connections of an anode rectifier. The condenser C is of

such a value that its impedance at radio frequency may be assumed negligible, while its impedance is very high to alternating E.M.F.'s at audio frequency. The rectifier would be considered perfect if the alternating potential across DE were an exact replica to scale of the *modulation* of the high frequency carrier wave applied at AB. The supposed characteristic of the valve, when operated with the anode resistance R, is shown in Fig. 2a. At a grid potential V the anode current is I. The application of an alternating potential between A and B causes variations v in grid potential which give rise to variations i in the anode current. The relation between v and i is conveniently drawn to a larger scale in Fig. 2b. On the application of a carrier wave $v = E \sin \omega t$ between A and B the anode current varies

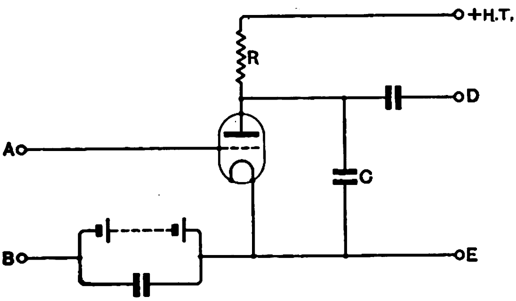


Fig. 1.—*Anode bend rectifier.*

sympathetically. Owing to the curvature of the characteristic the positive excursion of i is greater than the negative (Fig. 2b) and the average value of i becomes positive. That is to say, the receipt of the carrier wave causes an increase i_r (the rectified current) in the direct current flowing through the valve. The high-frequency alternating current flowing through the valve completes its circuit through the condenser C. The potential of the anode therefore falls by an amount $Ri_r = \overline{V}$, the rectified voltage. The relation between the amplitude E of the carrier wave and the consequent rectified voltage $\overline{V}$ may be represented by a curve such as Fig. 3a. Variations e in the amplitude of the carrier wave give rise to variations w in the value of the rectified voltage. These variations are shown to a larger scale in Fig. 3b. The process of transmission involves modulating the carrier wave, or impressing upon it a variation of amplitude, the extent and frequency of the variation being determined by the intensity and frequency of the note being transmitted (Fig. 4). It is such a modulated wave which is applied between A and B. The amplitude varies between $E(1 - m)$ and $E(1 + m)$

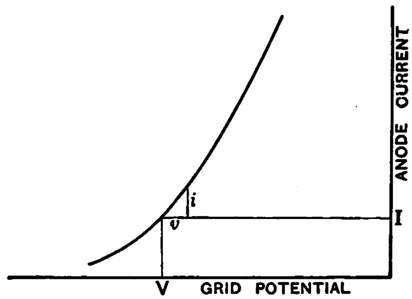


Fig. 2a.—*Relation between grid potential and anode current.*

where m is the fractional modulation (which rarely exceeds 20 per cent.). We may conveniently express the variation in E as

$$e = Em \sin pt \quad \ldots \quad (1)$$

Were the relation between e and w rectilinear, variation in rectified voltage w could be expressed by an equation of the form

$$w = k \sin pt \quad \ldots \quad (2)$$

and with this audio frequency potential available between D and E, distortionless rectification would be achieved. Unfortunately, the relation between w and e is usually more closely represented by a curve such as Fig. 3b. The effect is two-fold.

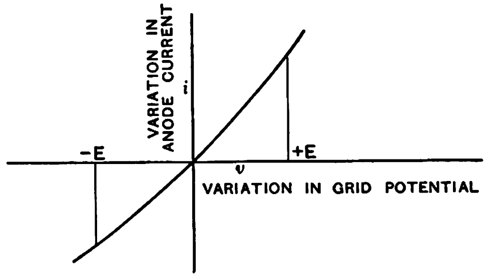


Fig. 2b.—*Relation between changes in grid potential and changes in anode current.*

In the first place modulation itself causes a further change in the anode potential and current, of small magnitude and importance; in the second place a sinusoidal variation of e does not result in a truly sinusoidal varia-

tion in w. The nature of the distortion thus introduced is illustrated in Fig. 5. The result is that the potential between D and E involves not only the true note of frequency $f = p/2\pi$ but also false audio components of frequency $2f$, $3f$, $4f$, etc.

It is proposed to examine later this distortion more carefully and to consider how it may be reduced.

4. Sensitivity of a Rectifier.

In practice the actual value of the rectified voltage produced as the result of applying a definite high-frequency wave to the grid is not of immediate importance. The sensitivity is measured by the relative magnitude of the *low-frequency alternating potential* to which the *modulation* gives rise. As has just been indicated, if the modulation is considerable, the low-frequency output is not of a simple sinusoidal form for a simple

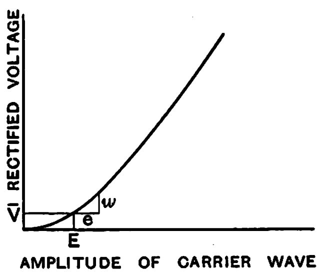


Fig. 3a.—*Relation between rectified voltage and amplitude of carrier wave.*

harmonic modulation. For small modulations, however, the low-frequency output is a pure replica of the modulation. Referring to Fig. 3a, a modulation Em sin pt of peak value e gives rise to a low-frequency alternating potential of peak value w. The sensitivity s may therefore be defined as

$$s = \frac{w}{e} = \frac{d\bar{V}}{dE} \quad \cdots \quad \cdots \quad (3)$$

Reference to curves given later (particularly Fig. 9) shows that the sensitivity increases towards a definite maximum limiting value. Distortion persists until this limiting value is approached.

5. Expression of Characteristic Curve.

In Fig. 2a is represented the relation between the anode current through a valve and the grid potential under certain defined conditions. From it Fig. 2b is deduced, expressing the relation between changes in anode current and changes in grid potential. Similarly Figs. 3a and 3b are drawn for

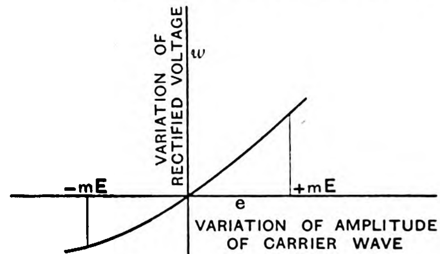


Fig. 3b.—*Relation between changes in amplitude of carrier wave and variation of rectified voltage.*

the amplitude of the carrier wave and the rectified potential. Curves of the general form of 2b and 3b are particularly important in studying rectification, and it is desired to express such a characteristic in general form. Fig. 6 represents such a characteristic; we wish to obtain an expression for y for any value of x. At the origin the rate of increase of y with respect to x, denoted by $\frac{dy}{dx}$, is represented by the slope of the tangent; this slope we may call b. For very small values of x the tangent approximates closely to the curve and the equation

$$y = bx \text{ or } y = x\frac{dy}{dx} \quad \cdots \quad \cdots \quad (4)$$

gives a sufficiently accurate value for y

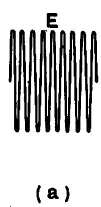


Fig. 4a.—*Carrier wave.*

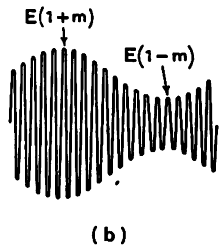


Fig. 4b.—*Modulated carrier wave.*

As x increases, however, the deviation of the curve from its tangent grows, and account must be taken of the fact that, not only has the curve a slope $\frac{dy}{dx}$, but the slope is changing.

The rate of change of slope, written $\frac{d^2y}{dx^2}$, we will denote by c. More exact expression requires that we must also take account of the fact that the rate of change of slope $\frac{d^2y}{dx^2}$ may itself be changing. The rate of change of $\frac{d^2y}{dx^2}$ is written $\frac{d^3y}{dx^3}$; its numerical value we will suppose to be c. And so on: in our search for accuracy we have arrived at the relations

$$\frac{dy}{dx} = b, \frac{d^2y}{dx^2} = c, \frac{d^3y}{dx^3} = d, \frac{d^4y}{dx^4} = f, \text{ etc.} \quad (5)$$

These relations lead us, by integration, to the equation

$$y = bx + \frac{cx^2}{\lfloor 2} + \frac{dx^3}{\lfloor 3} + \quad \text{etc.} \; .. \quad (6)$$

$$\text{or } y = x\frac{dy}{dx} + \frac{x^2}{\lfloor 2}\frac{d^2y}{dx^2} + \frac{x^3}{\lfloor 3}\frac{d^3y}{dx^3} + \quad \text{etc.} \quad (6a)$$

This is a particular case of Maclaurin's theorem. We see that a very small portion of the curve in the neighbourhood of the origin may be represented by its tangent $y = bx$; a more extended portion is approximated to with accuracy by the parabola $y = bx + \frac{1}{2} cx^2$;

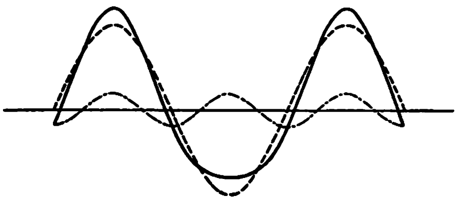


Fig. 5.—*The full line curve represents the output of the rectifying valve for a heavily modulated carrier when the relation between the rectified voltage and the amplitude of the carrier wave is not rectilinear. The two dotted curves show the principal components of the wave, one the true tone, the other an alien tone of double frequency.*

as the working range of the curve is increased it becomes necessary to take account of the terms involving the third, fourth and higher powers of x.

6. Rectified Current Due to Carrier Wave.

Applied to Fig. 2b equation (6) becomes

$$i = bv + \frac{cv^2}{\lfloor 2} + \frac{dv^3}{\lfloor 3} + \quad \text{etc.} \quad .. \quad (7)$$

If the carrier wave potential applied to the grid be expressed as

$$v = E \sin \omega t \quad .. \quad .. \quad (8)$$

then $(i)_a$, the *average* value of i, becomes

$$(i)_a = b(v)_a + \frac{c}{2}(v^2)_a + \frac{d}{6}(v^3)_a + \frac{f}{24}(v^4)_a + \quad \text{etc.} \quad .. \quad (9)$$

Now the average value of any odd power of

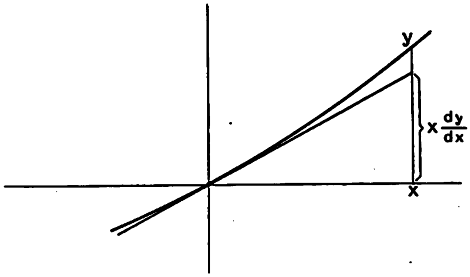


Fig. 6.—*For small values of x the tangent is a sufficient approximation to the curve and y may be assumed equal to $x\frac{dy}{dx}$. As x increases it becomes necessary to allow for the fact that $\frac{dy}{dx}$ is changing.*

a sine function over a complete period is zero. The average value of $\sin^2 \omega t$ is $\frac{1}{2}$ and of $\sin^4 \omega t$ is $\frac{3}{8}$. Hence the rectified current i_r is given by

$$i_r = (i)_a = \frac{cE^2}{4} + \frac{fE^4}{64} + \quad \text{etc.} \quad .. \quad (10)$$

For small values of the applied voltage all terms are negligible except the first and we then have

$$i_r = \frac{cE^2}{4} \quad .. \quad .. \quad (10a)$$

and the rectified voltage

$$\bar{V} = \frac{RcE^2}{4} \quad .. \quad .. \quad (10b)$$

It is seen that the efficiency of rectification increases rapidly with the signal voltage applied to the grid. The parabolic variation of the rectified current or voltage, represented by equations (10a) and (10b), is well known and is usually assumed as the basis of investigation of anode rectification (see *Wireless World*, 25th January, 1928, p. 90; 31st March, 1928, p. 311; 1st August, 1928, p. 129). It is shown later that this relation

does not describe the nature of the rectification sufficiently when the grid voltage is considerable.

7. Effect of Modulating the Carrier Wave.

Applied to Fig. 3b equation (6*a*) becomes

$$w = e\frac{dw}{de} + \frac{e^2}{\underline{|2}}\frac{d^2w}{de^2} + \frac{e^3}{\underline{|3}}\frac{d^3w}{de^3} + \frac{e^4}{4}\frac{d^4w}{de^4} + \text{ etc.} \quad .. \quad (11)$$

$$\text{or } w = e\frac{d\overline{V}}{dE} + \frac{e^2}{2}\frac{d^2\overline{V}}{dE^2} + \frac{e^3}{\underline{|3}}\frac{d^3\overline{V}}{dE^3} + \frac{e^4}{\underline{|4}}\frac{d^4\overline{V}}{dE^4} + \text{ etc.} \quad (11a)$$

If the fractional modulation is m, we have

$$e = Em \sin pt \quad .. \quad .. \quad (1)$$

Let us now examine the separate terms in equation (11*a*). Successively, they are of diminishing magnitude; if the modulation is reasonably small, only the first two terms are of any importance. The first term $e\frac{d\overline{V}}{dE}$ clearly represents a variation of the same frequency as the modulation, and, if it were the only appreciable term, there would be no distortion. The second term is proportional to $\sin^2 pt$, but

$$\sin^2 pt = (1 - \cos 2pt)/2 \quad .. \quad (12)$$

Hence this second term introduces a false oscillation of twice the true frequency. In addition there is a change in the rectified potential due to the curvature of the e/w characteristic. Again, the third term is proportional to $\sin^3 pt$, but

$$\sin^3 pt = (3 \sin pt - \sin 3pt)/4 \quad .. \quad (13)$$

This term, therefore, represents a modification of the magnitude of the fundamental tone, together with a false tone of three times the true frequency. Continuing this process we find that w may consist of the true note together with false notes of 2, 3, 4, etc., times the frequency of the fundamental.

8. Nature of the Distortion when the Rectification Curve is Parabolic.

We saw that when the grid swing is small the rectification curve is parabolic and can be expressed by

$$\overline{V} = \frac{RcE^2}{4} \quad .. \quad .. \quad (10b)$$

$$\text{whence} \quad \left.\begin{aligned} &\frac{d\overline{V}}{dE} = \frac{RcE}{2}, \frac{d^2\overline{V}}{dE^2} = \frac{Rc}{2}, \\ &\frac{d^3V}{dE^3} = \frac{d^4\overline{V}}{dE^4}, \text{ etc.} = 0 \end{aligned}\right\} \quad .. \quad (14)$$

$$\text{whence} \quad w = e\frac{RcE}{2} + e^2\frac{Rc}{4} \quad .. \quad .. \quad (15)$$

$$\text{giving us} \quad w = \frac{RcE^2}{4}(2m \sin pt + m^2 \sin^2 pt)$$

or

$$w = \frac{RcE^2}{8}(4m \sin pt + m^2 - m^2 \cos 2pt) \quad (16)$$

We see, therefore, that there is a second harmonic whose magnitude is $m/4$ times the magnitude of the fundamental. *The relative intensity of this false second harmonic is independent of the amplitude of the carrier wave*; a result which is not generally appreciated. If the modulation is 20 per cent. the false second harmonic is 5 per cent. of the fundamental, of sufficient magnitude to change definitely the quality of the note. In addition we see from equation (16) that, due to modulation, there is a change in the rectified potential of magnitude $Rcm^2E^2/8$. This change is of little importance: it affects slightly the transient "attack"; further, it is sufficient to enable the modulation to be estimated if care is exercised in reading the anode current.

9. Modification of Distortion by Increase of Grid Swing.

From what has been done it is clear that, so long as the valve characteristic is definitely curved, distortion is inseparable from rectification, the distortion being greatest on loud notes, and therefore then most objectionable. It is clear also that, for distortion to be small, all terms in equation (11*a*) should be small relative to the first; that is to say, the rectified voltage should bear a practically rectilinear relation to the grid swing. The double frequency term arises from the fact that, for small grid swings at least, the rectified voltage is proportional to the square of the grid swing (see equations (10*b*), (14), (15), (16)). It has been pointed out (see, for instance, *Wireless World*, 2nd May, 1928, p. 464) that the ideal characteristic consists of two straight lines (Fig. 7), the rectification point being B. For such a characteristic, having this sudden change at

B, the rectified voltage $\bar{V} = ke$. From such an ideal curve the usual valve characteristic differs considerably—or at least appears to do so (it is really a question of scale).

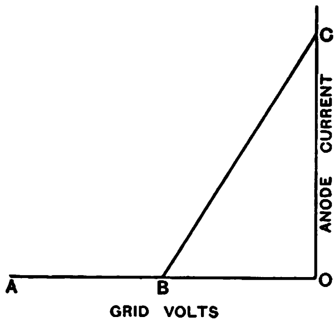


Fig. 7.—*Ideal characteristic for rectification (after McLachlan).*

If we consider the actual characteristic shown in Fig. 8 for a valve with a high anode voltage and large grid bias, we see that it consists of a well curved portion PQ together with portions RQ and PS which do not deviate greatly from the straight lines AB and BC. If the actual grid bias employed be represented by OB and the grid swing does not exceed a few volts, the rectification curve is practically parabolic and distortion occurs of the magnitude indicated in equation (16). If, however, we consider larger grid swings, sweeping over the greater portion of the characteristic as shown, it is clear that the

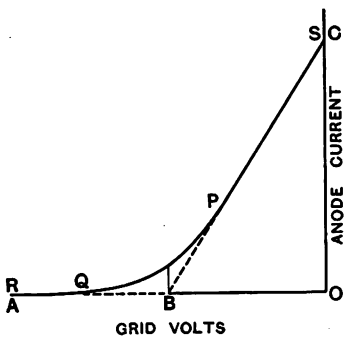


Fig. 8.—*Characteristic of rectifying valve. It is seen that as grid swing increases the effective deviation from the ideal A B C diminishes.*

effective deviation of the characteristic from the ideal ABC becomes less the greater the grid swing employed. If indeed the valve would permit of very large grid swings being employed (the bias being suitably high) the deviation would become almost negligible. Under such circumstances distortion would practically disappear.

10. Magnitude of Rectified Voltage.

Consideration of Figs. 7 and 8 shows that the ideal characteristic ABC is, for a given "slope," the most sensitive rectifier, and further that, with such a characteristic, the sensitivity is constant; that is to say, the rectified voltage is proportional to the grid swing. The slope of the characteristic is $M/(R + A)$, where M is the amplification factor of the valve, R the anode resistance, and A the valve impedance. The change in anode potential when the grid becomes one

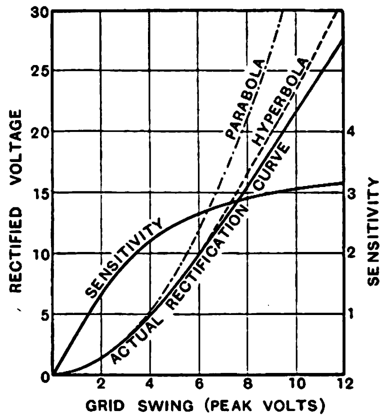


Fig. 9.—*Rectification curve for PM3 valve, $R = 130{,}000$ ohms, voltage about 190. The parabola most closely approximating to the curve for small values of the grid swing is also shown. The general features of the curve are more nearly those of an hyperbola, which is also shown. It is seen that for small grid swings the sensitivity is practically proportional to the swing. As the swing increases, however, the sensitivity approaches a limiting value.*

volt less negative is $MR/(R + A)$. It is easy to show that, if the rectification point is B, the rectified voltage is equal to the maximum change in anode voltage divided by π. We have, therefore, the sensitivity

$$s = \frac{M}{\pi} \cdot \frac{R}{R + A} \quad \ldots \quad \ldots (17)$$

Hence the sensitivity cannot exceed $0.318M$. For the particular valve treated later, $R = 130{,}000$, $A = 17{,}000$ and $M = 11.75$. Had this valve possessed the ideal characteristic the sensitivity would have been

3.31. The ideal rectification curve is shown in Fig. 15. The actual rectification curve (treated more fully later) is given in Fig. 9. It is seen that the actual sensitivity grows steadily from zero over the range for which the curve is plotted, the slope attaining a value of 3.15 for a grid swing (peak) of 12 volts, only 5 per cent. less than the slope of Fig. 15, the rectification curve derived from the ideal characteristic.

11. Actual Form of Rectification Curve.

It is found in practice that for a grid swing of a few volts the deviation of the rectification curve from the parabolic form is small. As, however, the grid swing is increased the departure from the square law becomes marked until, ultimately, the increase in the rectified voltage becomes little more than proportional to the increase in grid swing. These characteristics would be expected in view of the considerations put forward in the previous section. Were the relation between the rectified voltage and the grid swing truly rectilinear over the extent of the modulation, distortion would be absent; in practice the relation becomes sufficiently rectilinear for distortion to be much reduced. Fig. 9 shows an actual rectification curve (the method of obtaining it is given later) and on the figure is shown also the parabola to which it approximates for small values of the grid swing.

12. General Expression for the Distortion.

It has been pointed out that in general the modulation is sufficiently small for all terms in equation (11a) to be neglected except the first two. Under these circumstances the only distortion of any moment is the double frequency note. Its amplitude divided by the amplitude of the true note may be taken as a *measure of the distortion*. The amplitude of the double frequency note is $E^2m^2\dfrac{d^2\overline{V}}{dE^2} \div 4$ and of the true note $EM\dfrac{d\overline{V}}{dE}$. The distortion may, therefore, be represented by the ratio

$$\rho = \frac{Em}{4}\,\frac{d^2\overline{V}}{dE^2}\bigg/\frac{d\overline{V}}{dE} \quad \ldots \quad \ldots (18)$$

For a parabolic rectification curve this ratio is equal to $m/4$ for all values of E.

13. Hyperbolic Rectification Curve.

The characteristics of the practical rectification curve have already been described in section 11. They resemble more closely the features of an hyperbola than a parabola. Fig. 9 shows an hyperbola which represents the rectification fairly closely. The general equation to an hyperbola is

$$\frac{\overline{V}}{b} + 1 = \sqrt{1 + \frac{E^2}{a^2}} \quad \ldots (19)$$

For the case shown in Fig. 9 the values of the constants are $a = 6.6$, $b = 28.75$.

From equation (19) we obtain

$$\frac{d\overline{V}}{dE} = \frac{b}{a}\cdot\frac{E}{\sqrt{a^2+E^2}}$$

$$\frac{d^2\overline{V}}{dE^2} = \frac{ab}{(a^2+E^2)^{3/2}}$$

whence $$\frac{Em}{4}\,\frac{d^2\overline{V}}{dE^2}\bigg/\frac{d\overline{V}}{dE} = \frac{m}{4}\cdot\frac{a^2}{a^2+E^2} \quad \ldots (20)$$

The expression given in this equation shows how the distortion varies with E for a hyperbolic rectification curve. For small values of E the distortion is the same as that when the relation is parabolic, but as E becomes comparable with a the distortion falls considerably (Fig. 10).

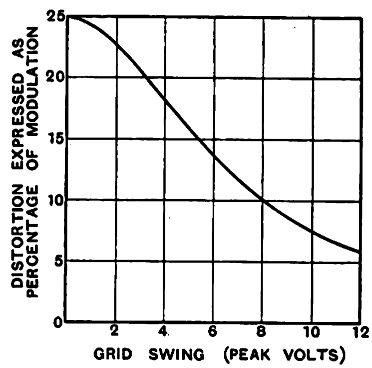


Fig. 10.—*Showing reduction of distortion with increasing grid swing—hyperbolic rectification curve (see* Fig. 9).

14. Determination of Rectification Curve.

A complete investigation of the best conditions of operation for any particular valve involves an accurate determination of the rectification curve. If means are available this may be determined directly

(see Sowerby, *The Wireless World*, March 21st, 1928, p. 309). Commonly, however, the experimenter is not in a position to effect the determination in this manner. He often has, however, sufficient apparatus available to determine the grid-volts/anode-current characteristic of the valve (with the working anode resistance) with accuracy; from this characteristic the rectification curve may be deduced. An interesting method is given by Barclay in *E.W. & W.E.*, 27th August, 1927, p. 459. The writer has applied this method to a parabolic characteristic and found it surprisingly accurate. It appears, however, to be unsuitable to the type of characteristic which is most desired from the point of view of rectification—a curve of the form of Fig. 8. For such a curve there seems to be no satisfactory alternative to actual calculation; if this is carried out in a systematic tabular form it need not involve excessive labour. Referring to Figs. 2a and 2b it is seen that it is desired to determine the value of i_r when v oscillates harmonically between the limits $-E$ and $+E$. This is clearly equal to the "time average" of i as v passes from $-E$ to $+E$. This can be determined by measuring i at a number of convenient equally time-spaced intervals and obtaining the mean. It is sufficient to measure at each 10 electrical degrees, that is to say from $E \sin -85$ deg., $E \sin -75$ deg., etc., to $E \sin +85$ deg.

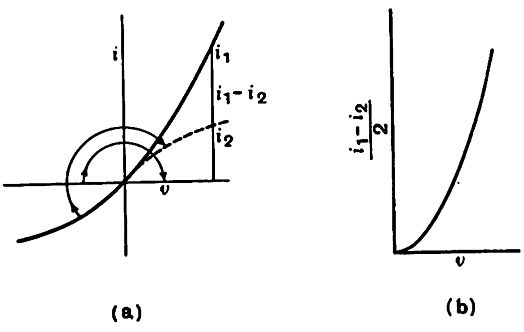


Fig. 11.

There is an obvious simplification; corresponding to each positive value of i (which we may call i_1) with v positive there is a complementary negative value of i (which we may call i_2—numerically less than i_1) for an equal negative value of v. The time average of i is therefore equal to the time average of $(i_1 - i_2)/2$ reckoned between $v = 0$ and $v = E$. It is convenient to plot this curve to a larger scale. Its derivation is illustrated by Fig. 11 ((a) and (b)). Fig. 11(a) is obtained by plotting i_2 below i_1 (swinging the third quadrant of Fig. 2b into the first). From a curve of the form of Fig. 11(b), drawn for any particular value

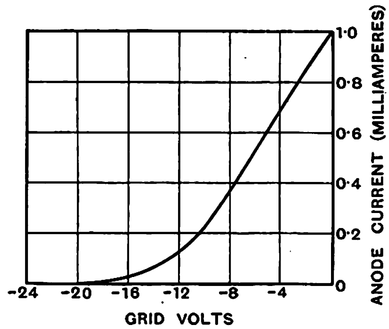


Fig. 12.—*Characteristic for PM3 with anode resistance of* 130,000 *ohms.*

of the grid bias, values of $(i_1 - i_2)/2$ for each 10 deg. from 5 deg. to 85 deg. may be tabulated for various values of e and the corresponding values of i_r thus determined. Fig. 12 gives the characteristic for a P.M.3 with a series resistance of 130,000 ohms, at a potential of about 190 volts, Fig. 13 the deduced curve for $(i_1 - i_2)/2$ when the grid bias is 12 volts. The table given is that part of the actual table prepared which relates to $E = 5$ volts.

TABLE.

θ Deg.	$E \sin \theta$.	$(i_1 - i_2)/2$.
5	0.436	.0009
15	1.294	.0081
25	2.113	.0230
35	2.868	.0406
45	3.535	.0600
55	4.096	.0762
65	4.532	.0940
75	4.830	.1007
85	4.981	.1050
	Total	.5085

giving $i_r = .5085/9 = .0565$ mA.
whence $\bar{V} = 130{,}000 \times .0565/1{,}000 =$ 7.345 volts.

Repeating for various values of E the rectification curve is obtained, shown for the conditions cited in Fig. 9.

15. Derivation of Distortion from Rectification Curve.

The rectification curve having been obtained the curves representing $\frac{d\bar{V}}{dE}$ and $\frac{d^2\bar{V}}{dE^2}$ are readily deduced (see Appendix). For a P.M.3, under conditions already cited, these curves were determined, and in Fig. 14 is shown the deduced curve of distortion. It is seen that for small grid swings the distortion is practically uninfluenced by the magnitude of the swing, but with swings of the order of 5 to 10 peak volts the distortion is reduced very considerably. Two features of this curve are of particular interest. In the first place the distortion for large values of the grid swing is less than it would be were the rectification curve of the form of the hyperbola shown in Fig. 9. This is due to the fact that the actual rectification curve approaches a straight line more closely than the hyperbola does when the grid swing is great. In the second place it is noticed that for small grid swings the distortion actually increases slightly. This is due to the fact that the rectification curve in the neighbourhood of the origin is even more sharply curved than a parabola, the rectified voltage being proportional to rather more than the square of the grid swing.

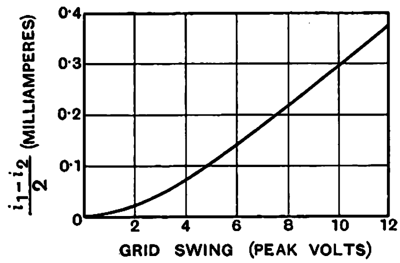


Fig. 13.—*Curve deduced from* Fig. 12 *in the manner indicated in* Fig. 11 ((a) *and* (b)). *Grid bias* 12 *volts.*

16. Choice of Grid Bias.

A consideration of the ideal characteristic curve illustrated in Fig. 7 reveals the fact that were the grid bias not properly chosen grave distortion might occur. With correct adjustment of the bias to the point B the rectification curve is a straight line PT (Fig. 15). If the bias is incorrectly adjusted no rectification occurs until the grid swing is sufficiently great to sweep past the point B. The curve $PQRS$ of Fig. 15 has been drawn for a grid bias of 14 volts, the correct bias (corresponding to the point B—Fig. 7) being $12\frac{1}{2}$ volts. The rectification curve consists of two portions PQ and QRS, the portion RS being practically linear. For grid swings of 4 to 10 volts peak distortion is negligible. Below 4 volts distortion is felt. With a grid swing of $1\frac{1}{2}$ peak volts the distortion would be very bad indeed.

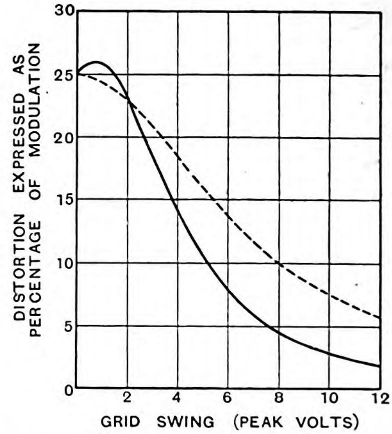


Fig. 14.—*Showing reduction of distortion with increasing grid swing, grid bias* 12 *volts. The full curve shows the actual distortion; the dotted curve is the distortion calculated for a hyperbolic rectification curve* (*see* Figs. 9 *and* 10).

These considerations indicate the desirability of fixing the grid bias so that the sharply curved portion of the characteristic (Fig. 8) is near the middle of the swing. This is practically the point where $\frac{d^2i}{dv^2}$ has its maximum value. If the grid swing is small we have seen that the rectified voltage is expressed by

$$\bar{V} = \frac{RE^2c}{4} = \frac{RE^2}{4} \cdot \frac{d^2i}{dv^2} \quad \ldots (9c)$$

The correct value of the grid bias for minimum distortion is therefore the same as that for maximum sensitiveness to weak signals. It is clear that so long as the grid swing is sufficiently great very exact adjustment of the bias is not essential. In any case the fixing of the bias is a simple matter in practice.

The effect of various values of the bias is shown in Fig. 16. As the bias is increased

from 9 to 11 volts the improvement is progressive. Further increase to 12 volts increases the distortion for grid swings below 4 volts. For large grid swings the higher bias is better. Maximum sensitiveness for this rectifier is obtained with a grid bias between 11 and 12 volts, and it is seen that this bias is also approximately that which gives minimum distortion. The point so obtained is not in the centre of the sharply curved portion but rather towards the straight part of the characteristic. Calculations have been included only for one particular valve, but examination of a considerable number of valves of different constants indicates that the results are almost equally applicable to them. There is a tendency for the curved portion of the characteristic to be rather shorter for valves of a high amplification factor, and for such valves a smaller grid swing may be employed, giving roughly (taking into account the increased amplification) the same low frequency output. There are, however, other objections to the use of valves having too high an amplification factor when the best quality is sought and it is desirable to use a valve whose

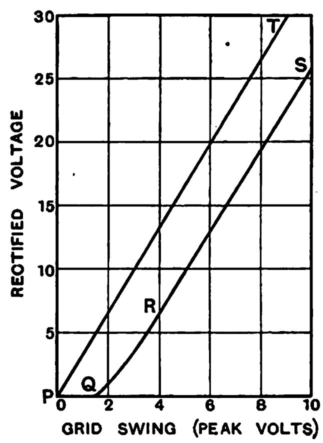


Fig. 15.—*Rectification curves corresponding to ideal characteristic of* Fig. 7. *PT is drawn for the correct grid bias of* $12\frac{1}{2}$ *volts (B,* Fig. 7*), PQRS for a grid bias of* 14 *volts. If the grid swing exceeds* 4 *volts in the latter case, the distortion is small. With a grid swing of* $1\frac{1}{2}$ *volts the distortion is great. When the grid bias is correctly adjusted rectification is distortionless for all values of the grid swing.*

amplification factor is not greater than 15. For such valves, with grid swings of 2 or 3 peak volts, the distortion is not much less than with very small swings. As the grid swing increases to 10 volts peak and above, the distortion is reduced to quite a small value. If we assume that we have to legislate

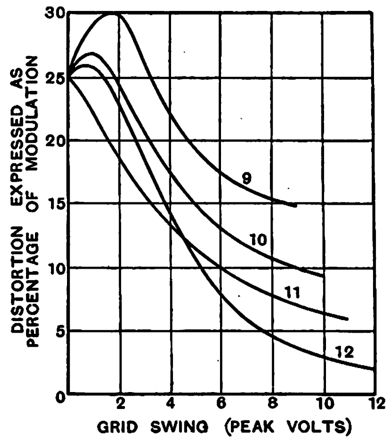


Fig. 16.—*Showing variation of the distortion characteristic with the grid bias. The corresponding grid bias (in volts) is indicated on each curve.*

for a grid swing due to carrier wave alone of 10 volts peak, and that the maximum modulation is 20 per cent., it is clear that the grid bias must be at least 12 volts if the grid is never to become positive. Of course a high anode potential is necessary; that is usually available. The author has yet to find a valve by a reliable maker which will not stand up to an anode potential of 200 volts under anode rectification conditions.

It has been seen that the sensitiveness of rectification is but little affected by the value of the anode resistance so long as it is several times the impedance of the valve. There is therefore no difficulty in forcing the bend of the characteristic towards the left so that rectification is obtained with a sufficiently great grid bias. For instance, if it is found that greatest sensitiveness is obtained when the grid bias is 9 volts, a reduction of the anode resistance will shift the characteristic so that the grid bias has to be increased.

17. Conclusion.

It is usual in considering the design of a set to decide the grid swing necessary on the output valve and to calculate backwards to determine the requisite low-frequency amplification to be employed in view of the

anticipated signal strength at the grid of the rectifier. The author would suggest that when the best quality is desired both the output grid voltage and the grid swing of the rectifier should be fixed and both high-frequency and low-frequency amplification then designed to suit. It has been seen that when the grid voltage sweeps well over the straight portions of the characteristic the sensitivity approaches 0.318M. Using a valve whose M value is 12 with a 20 per cent. modulation on a grid swing of 10 volts, the peak value of the low-frequency potential is rather lower than $12 \times 2 \times 0.318 = 7.64$ volts. The probable potential (peak) would be about 7 volts. It is clear that this is sufficient to load a pentode fully without further amplification. Commonly a transformer is used with a rectifier output of not more than 2 volts. The author finds that the quality is definitely improved by omitting the transformer and increasing the rectifier output. In the previous section it was pointed out that it is desirable to aim at roughly the same rectifier output, whatever the M value of the rectifier employed. A suggested value for that output is not less than 7 volts peak on a 20 per cent. modulation. If the final stage consists of an ordinary triode working on a grid bias of 30 volts the intermediate stage should give an amplification of 4. The author uses a valve of M value 7 for this stage and makes use of only one half its amplification. The full amplification is available when weak signals are being received; the quality is then not likely to be too good.

It is seen that the perfection of a rectifier is determined entirely by the form of the characteristic. In this respect, so long as the grid swing is sufficiently great, no other arrangement can surpass an anode-bend rectifier. A good deal has been written of late respecting the diode rectifier. Its characteristics must be generally the same as those of the anode-bend detector; when the damping which it introduces is remembered it is clear that its behaviour must compare poorly with that of the more conventional arrangement when properly designed.

APPENDIX.

A Note on the Differentiation of Curves.

It is usually considered that the differentiation of an experimental curve admits of errors which may be considerable; a second differentiation may result in these errors being greatly magnified. The errors arise in two distinct ways :—

(*a*) Errors of observation and plotting.

(*b*) Subsequent errors in determining the slope of the curve; these arise chiefly owing to the curve not being correctly drawn between the observed points (even if the observed points themselves are accurate).

If a curve is correctly drawn (for instance, if an hyperbola is calculated and plotted for a large number of points) it is surprising how accurately its slope at any point may be determined by the simple process of drawing the tangent at that point. When, however, the number of observed points is limited, considerable errors may be introduced in the slope of the curve in plotting, particularly when the curvature is great. Methods of plotting should therefore aim at (i) eliminating errors of observation as far as possible,

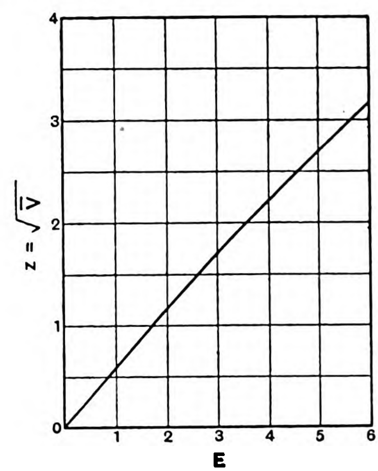


Fig. 17.—*This curve represents another way of graphing the relation represented in* Fig. 9 *by the lower part of the hyperbola. From such a curve, approximating as it does to a straight line,* $\frac{d\bar{V}}{dE}$ *can be determined with much greater accuracy than it can from the original hyperbola.*

(ii) graphing the curve in such a way that deviations from its true form (due to bad draughtsmanship) are likely to be but small.

When any relation can be expressed in such a way that its graph is a straight line, or approximately a straight line, both these

aims are achieved. Not only is it then possible to measure the slope with considerable accuracy, but the slope so measured is likely to approximate very closely to the slope of the true curve imagined prepared from theoretically perfect observations.

If we consider as an example the rectification curve of Fig. 9, this approximates to a rectilinear form when E exceeds 6 volts. For this range errors of graphing are likely to be small and the slope and rate of change of slope can be determined with very reasonable accuracy. When, however, we consider the lower part of the curve conditions are different: the rate of change of slope is considerable; errors of plotting are less obvious, and direct measurement from the curve as drawn is open to inaccuracy. The relation may, however, be expressed in a graph which is more or less rectilinear by plotting $z = \sqrt{\bar{V}}$ against E instead of $\bar{V}$ against E. This curve is shown in Fig. 17; its slope $\frac{dz}{dE}$ can be determined with accuracy.

But we have $\bar{V} = z^2$

therefore $$\frac{d\bar{V}}{dE} = 2z\frac{dz}{dE}$$

Hence $\frac{d\bar{V}}{dE}$ is readily calculated from the values of $\frac{dz}{dE}$. For this range the relation between $\frac{d\bar{V}}{dE}$ and E is approximately rectilinear, and errors of measurement are largely eliminated by plotting. The determination of $\frac{d^2\bar{V}}{dE^2}$ from $\frac{d\bar{V}}{dE}$ over this range presents no difficulties.

As a check upon this, and the direct, methods of calculation, the hyperbola

$$\frac{\bar{V}}{28.75} + 1 = \sqrt{1 + \frac{E^2}{(6.6)^2}}$$

was plotted for values of $E = 1, 2, 3, 4, 5, 6$. The values of $\frac{d\bar{V}}{dE}$ determined directly from the curve exhibited an average error of 1.8 per cent. and a maximum error of 3.3 per cent. When, however, the curve connecting z and E was used, the average error in the values of $\frac{d\bar{V}}{dE}$ was reduced to 0.44 per cent., the maximum error being 1.1 per cent.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Push-Pull Amplification.

To the Editor, E.W. & W.E.

SIR,—It was with interest that I read Mr. Aughtie's article on Push-Pull Amplification in this month's *E.W. & W.E.*, because about a year ago I hit upon exactly the same scheme.

The suggestion was made to several of my friends, and in several cases the arrangement is still in use with very satisfactory results. The advantages claimed by Mr. Aughtie do not seem to include those which seem to me to be the most important, namely: (1) Back-coupling through the H.T. supply is eliminated with respect to *both* stages of L.F. (2) The H.T. for all four L.F. valves may be taken direct from D.C. mains without smoothing. For reasons which I have pointed out elsewhere, mains noises are not reproduced. (3) The wave from distortion due to characteristic curvature is cancelled out in the output stage. Unfortunately this last point does not apply to the first pair of valves, because the input to V_2 (Mr. Aughtie's figures) has already passed through one additional distorting stage.

This fact should be added to the reasons why a completely silent point cannot be attained, and it seems to me to be of more importance in this respect than those given by Mr. Aughtie. I was never able to achieve perfect silence even with a single frequency input, and the weird noises I got did not suggest anything quite so simple as a phase displacement, as this ought to produce a pure tone.

The arrangement I use is slightly different from either of Mr. Aughtie's suggested forms, both of which I rejected. The potentiometer grid leak has the disadvantages he mentions, while I never succeeded in obtaining a reliable anode resistance which would carry an appreciable anode current and in which a continuously variable tapping could be provided. The difficulty is easily surmounted, however. I simply connect a high resistance potentiometer between the two anodes V_1 and V_2 and take the slider to the grid of V_2 through the usual condenser. As the potentiometer is

connected between two points of equal D.C. potential, it is only called upon to carry a small A.C., and therefore one of the many potentiometers sold as volume controls is quite satisfactory.

Stratford-on-Avon. P. G. DAVIDSON.

Frequency Modulation.

To the Editor, E.W. & W.E.

SIR,—Following Mr. Holmblad's and Mr. Makey's letters in the *E.W. & W.E.* issues of May and July, I would like to submit the following remarks regarding the frequency band width of an alternating "carrier" current of constant amplitude, the frequency of which is alternately varied between two values ω_1 and ω_2 under the action of a modulating vibration of frequency m, the frequency difference $k = \omega_2 - \omega_1$ being proportional to the amplitude of the modulating vibration.

The frequency m being small with respect to the carrier frequency, there will generally be at least one frequency value ω_3 of the carrier current, comprised between ω_1 and ω_2, which is an exact multiple of the frequency m. The frequency of the carrier current varying, during every cycle of the modulating vibration, from the lower value ω_1 to the higher value ω_2 and back to the value ω_1, the carrier current goes through the frequency value ω_3 *twice* during every cycle of the modulating vibration and may be considered every time to assume this frequency value ω_3 for a short period of time, covering say 3 or 4 cycles of the carrier current. The carrier current thus comprises a component current of frequency ω_3, flowing in the circuit $2m$ times per second and for but a few cycles every time, and having hence an amplitude which is modulated at the fundamental frequency $2m$ between zero and the constant maximum amplitude of the actual carrier current. The frequency band width of this ω_3 frequency component is thus at least equal to $4m$ cycles (and is, in fact, much greater, since this ω_3 frequency current is very far from being sinusoidally modulated at the frequency $2m$).

The same remarks apply as well to all other components the respective frequencies of which, comprised between ω_1 and ω_2, are exact multiples of the frequency m. And they may be considered as approximately applying to the other intermediate frequency components of the carrier current—and in particular to the components of frequencies $\omega_2 - a$ and $\omega_1 + a$ differing from the extreme values ω_1 and ω_2 by as small an amount a as desired.

It follows that the *minimum* value of the frequency band width of the constant-amplitude, frequency-modulated carrier current is approximately equal to

$$[(\omega_2 - a) + 2m] - [(\omega_1 + a) - 2m]$$
$$= \omega_2 - \omega_1 - 2a + 4m = k - 2a + 4m.$$

Expressed in words, and neglecting the small factor $2a$, the minimum value of the frequency band width is equal to the frequency variation k (proportional to the modulating amplitude) plus four times the modulating frequency m.

This is more than twice the frequency band width of an ordinary amplitude-modulated, constant frequency carrier current, for the same modulating vibration.

A mathematical formulation of the above remarks is an extremely easy matter, but is not carried out here in order not unduly to lengthen this note.

Briefly summarising and picturising the above, a frequency-modulated, constant amplitude transmitting set may be thought of as replaced by a multiplicity of heavily damped spark transmitters having respectively frequencies comprised between ω_1 and ω_2, and operating successively in a given order at a rate of $2m$ sparks per second.

Paris. H. LAUER.

To the Editor, E.W. & W.E.

SIR,—Mr. G. H. Makey, in his criticism of my letter on the above subject, attempts to show that I am in error in my conception of the frequency modulation system. Unfortunately the formula Mr. Makey arrives at in his letter cannot be correct, since it is the expression for a wave of which the frequency is oscillating between steadily increasing limits.

As already pointed out in my first letter, the "instantaneous" cyclic frequency of a wave given by the expression

$$i = A \sin [f(t)] \quad .. \quad .. \quad .. \quad .. \quad (1)$$

may be determined by differentiating $f(t)$ with regard to the time. This may easily be shown: The "instantaneous" frequency is in fact nothing but a measure for the momentary variation of the angle with regard to the time, *i.e.*, the momentary angular velocity; if for instance, the angle be constant ($i = A \sin \omega$), the frequency is zero; if the angle be increasing linearly ($i = A \sin \omega t$), the frequency is constant (ω), and so on.

The expression given by Mr. Makey is

$$i = A \sin (\omega t + k \,.\, t \,.\, \sin mt) \quad .. \quad .. \quad (2)$$

Differentiating the angle with regard to the time we get the instantaneous frequency

$$n = \omega + k \sin mt + m.k.t.\cos mt \quad .. \quad .. \quad (3)$$

which is oscillating between steadily increasing limits.

As shown above, the expression (2) is not a periodic function of time, and consequently it cannot be expanded in fourier series.

My pessimism with regard to frequency modulation does not seem to be shared, however, by everybody, judging from the number of patents described in *E.W. & W.E.* since my first letter.

N. E. HOLMBLAD.

Copenhagen.

Moving Coil Loud Speakers.

To the Editor, E.W. & W.E.

SIR,—In the article on M.C. Speakers (*E.W. & W.E.*, July, 1929) Mr. Cosens cites a motional capacity of 0.74 mfd. which he attributes to Mr. L. E. T. Branch. So far as I am aware, the *equivalent* electric circuit, the term "motional capacity" and data pertaining thereto were first given by me in *The Wireless World*, 23rd March, 1927. The figure 0.74 mfd. was taken by Mr. Branch—with reference—from this article. In this and other articles

(*Handbook on Loud Speakers*, completed June, 1926, and published March, 1927, also *W.W.*, 13th April, 21st Sept., 1927, 11th, 18th, 25th July, 8th Aug., 10th, 17th October, 28th November, 1928, and 10th April, 1929), I have given a good deal of data pertaining to the performance and design of M.C. Speakers. The mathematical analysis—formulated early in 1926 prior to the instalment of the speaker I designed for the Science Museum—being beyond the scope of *W.W.*, was published in the Supplementary issue of the *Phil. Mag.*, June, 1929. Due to delay in publication, Mr. Cosens has unfortunately repeated part of my *Phil. Mag.* Paper.

I think the term " adherent " air is a misnomer. The added mass is caused by divergence of the waves from the disc, and not by air " adhering " thereto. Rayleigh's nomenclature ought to stand, viz., " accession to inertia." I introduced the question of accession to inertia in my *W.W.* article 30th March, 1927, and in my book on Loud Speakers, pp. 64, 65. These publications antedate by two years the references cited by Mr. Cosens.

I have been alive to lack of diaphragm rigidity since 1926. In January, 1927, I filed a patent (now 288713) in which the " break-up " of a diaphragm is used in a reed-driven speaker (natural frequency 2,600 ∼), now known as the " Amplion Lion." During vibration the radiation from alternate areas is of opposite sign and a degree of neutralisation occurs. This, together with diaphragm attenuation results in the diaphragm contributing very little to the radiation above about 8,000 ∼ (see L.S., chap. 4 and p. 56, also *W.W.*, 10th, 17th July, 1929). The effect of transients in various speakers is shown in the records given in *W.W.*, 10th April, 1929. I think the upper register in M.C. Speakers is partly due to concertina action of coil and diaphragm, i.e., the elasticity of the neck of the coil. (*W.W.*, p. 542, 17th October, 1928, also 10th April, 1929.)

Neither Mr. Cosens' Paper nor my *Phil. Mag.* Paper can purport to be an orthodox theory of the M.C. Speaker. Owing to (1) inadequate rigidity of the complete system thereby giving natural frequencies well within the audible register, (2) the shape of the diaphragm and its complex radiation properties which are accentuated by its concavity and convexity, (3) the velocity down the diaphragm being less than that of sound in air, the problem would appear to present grave analytical difficulties. Nevertheless, with Mr. Butterworth's unique mathematical powers the solution is almost a foregone conclusion.

N. W. McLachlan.

London,
July, 1929.

On the Writing of Scientific Papers.

To the Editor, E.W. & W.E.

Sir,—As a teacher of " Wireless," I am tempted, by Mr. Colebrooke's recent article on the writing of scientific papers, to draw attention to a subject on which authors are extremely apt to mislead students.

I refer to the relation between the electric and magnetic fields of a wireless wave. Although this problem has been clearly discussed by Dellinger, Moullin, and many others, the old fallacies about these fields and particularly about their effects on loops and open aerials are astonishingly persistent.

It is therefore specially unfortunate that scientific papers by the most eminent authorities should not infrequently include ambiguous statements, which are liable to encourage and prolong the life of these ancient heresies.

Here are a few examples :—

" Since the aerial responds to E_z, and the loop to H_x." (Professor Appleton, *Journal I.E.E.*, Vol. 66, p. 874.)

" One responds to the electric, the other to the magnetic oscillation." (Sir Oliver Lodge, *Modern Wireless*, Vol. I., No. 1, p. 9.)

" We may also use the oscillatory magnetic force in the wave as a method of receiving signals." (J. A. Ratcliffe, *The Physical Principles of Wireless*, p. 55.)

" The Nodes " (of the electric and magnetic fields) " will be situated in different places according to which of these fields is under consideration." (R. H. Barfield, *Journal I.E.E.*, Vol. 67, p. 787.)

" The states of maximum and minimum strain " (of the electric and magnetic fields) " are not simultaneous." (Capt. Eckersley and Mr. Howe, *Journal I.E.E.*, Vol. 67, p. 788.)

To varying extents all these statements are ambiguous and misleading to the uninitiated. So I feel justified in saying that if a special plea for care on this subject could be added to your general advocacy of attention to the arrangement and composition of papers, many teachers would be grateful, in addition to

F. C. Curtis,
Captain, R. Signals.

Book Review.

Concerning High-frequency Stabilisation by Piezo-electric Oscillators. A 12-page brochure issued by Adam Hilger, Ltd.

Messrs. Hilger have a world-wide reputation for the manufacture of optical instruments of the highest class and for the accurate working of glass and quartz in connection therewith. They are therefore well equipped for the closely allied problem of the construction of piezo-electric oscillators and resonators. The brochure received deals only with the former, a separate brochure being issued dealing with resonators. The first five pages are devoted to an historical and general account of the subject, with several references to original papers. This is followed by a description of the mounting devised by the firm and a discussion of its advantages and of the precautions to be adopted in its use. The crystal plate is placed between two brass electrodes in a glass tube, the whole being enclosed in an ebonite case about 2in. diameter and 1in. high. The length of the glass tube is carefully adjusted so as to ensure the proper air-gap between the crystal and the upper electrode.

The brochure will prove of interest to anyone who has to manipulate piezo-electric oscillators.

Abstracts and References.

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PROPAGATION OF WAVES.

DOUBLE AND MULTIPLE SIGNALS WITH SHORT WAVES. SHORT RANGE ECHOES WITH SHORT WAVES.—E. Quäck and H. Mögel. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 791–823 and 824–829.)

English version of the paper and supplement dealt with in June Abstracts, pp. 322 and 323.

EXPERIMENTELLE UNTERSUCHUNGEN DER VERÄNDERUNG DER DIELEKTRIZITÄTSKONSTANTEN EINES SEHR VERDÜNNTEN GASES DURCH ELEKTRONEN (Experimental Investigations of the Alteration of the Dielectric Constant of a Very Rarified Gas by Electrons).—L. Bergmann and W. Düring. (*Ann. der Phys.*, 7th May, 1929, 5th Series, V. 1, No. 8, pp. 1041–1068.)

After sketching the theory of the Heaviside layer, the writers refer to the investigations of Eccles, Salpeter, Larmor, Lassen and Elias on the dielectric constant and conductivity of an ionised gas traversed by electric waves. These all lead to the same main result—a diminution of the dielectric constant which increases with increasing ionisation, and an absorption of the passing wave owing to the conductivity of the ionised gas. The Larmor equations differ slightly from those of the other workers, owing to different assumptions, but are fundamentally the same. They then describe the experimental investigations of van der Pol (2nd Drude method) giving the resulting curve for a wavelength of 150 cm., and point out that the greater part of this allows little to be learned of the dielectric constant, but that one portion definitely shows a diminution—though only qualitatively. They then describe the experiment of Gutton and Clément (who also used the effect of the ionisation on a condenser, but in a different way). These workers found a diminution of dielectric constant, in the case of small ionic densities, but for great densities they found an increase of the constant—contrary to the Eccles theory. This discrepancy they explained on the idea that at great densities the ions suffer not only the frictional force of Eccles' theory but also a mutual attraction, and are bound in a state of equilibrium. Rybner, however (March Abstracts, p. 146), points out that the elastic force thus postulated for an explanation of the increase of dielectric constant is not necessary, since the apparent increase may be due to the apparatus used by Gutton and Clément.

The writers, considering that a decision can only be made by a new test with improved apparatus, to give quantitative instead of only qualitative results, have now made such a test, avoiding the difficulties of the former experiments by the use of highly rarified gas. This plan practically eliminates the frictional effect. They also avoid the complication of the presence of both ions and electrons, dealing only with electrons, using the same 2nd Drude method and obtaining the electrons from a hot cathode; an auxiliary electrode (grid) being employed to destroy the space charge. The vacuum was so high that the electron free paths were large in comparison with their oscillation amplitudes in the electrical oscillating field (this is the case at a pressure of $1\text{–}2 \times 10^{-5}$ mm.) Wavelengths used ranged from 100 to 240 cms.

Results showed that the presence of electrons produced a diminution of dielectric constant which increased with increasing density of electrons. So far as quantitative measurements were possible, the absolute value of the constant agreed with theory. Dispersion (the effects on gradually increasing wavelengths, keeping a constant electron density) was also investigated and the results agreed with theory.

ÜBER DIE EIGENSCHWINGUNG FREIER ELEKTRONEN IN EINEM KONSTANTEN MAGNETFELD (The Natural Vibration of Free Electrons in a Constant Magnetic Field).—S. Benner. (*Naturwiss.*, 15th February, 1929, V. 17, pp. 120–121.)

When free electrons move in a constant magnetic field, they describe spirals round the lines of force. The number of turns of spiral traversed in unit time is independent of the electron speed when this is small, and depends only on the charge e, the mass m, and the field strength H; it is $eH/2\pi m$. But if in addition to the magnetic field an alternating electric field perpendicular to this acts on the electrons, the latter fall into strong oscillation due to a form of resonance, when the frequency of this field is nearly equal to the rotation-period of the electrons. The dielectric constant and the conductivity of the space are strongly altered by

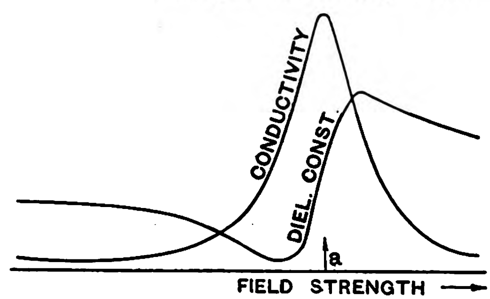


Fig. 1.—*Theoretical.*

a change in the frequency of the field: or, on the other hand, the field may be kept at a constant frequency and the electron rotation-period can be varied by varying the strength of the magnetic field. Fig. 1 shows the theoretical curves which should be obtained by such a process. Appleton

and Barnett, Nichols and Schelleng, and later Pedersen, have based on this effect a theory of the Heaviside layer: the present writer has now carried out experiments to test this. A cylindrical oscillator valve (Schott, Type *N*) was paralleled with a variable condenser to form an oscillating circuit in which the anode/grid capacity was effective. A weak field between filament and grid drove electrons across the space between grid and anode. The valve was surrounded by a co-axial magnetising coil. The resonance curve of the system was plotted for a constant frequency and varying field-strengths, and from this the changes in decrement and capacity were calculated. Fig. 2 gives the results for a 7.9 m. wavelength.

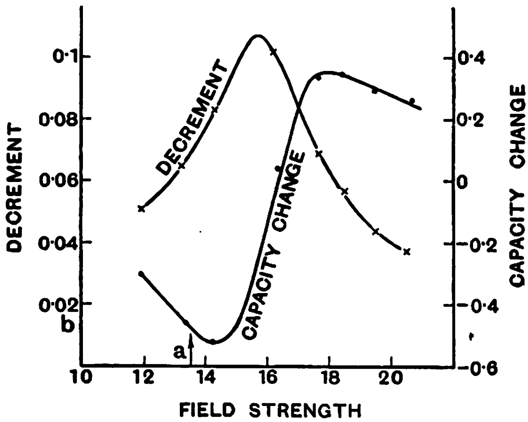


Fig. 2. — *Experimental. a. Field strength at which the electron frequency = field frequency. b. Decrement for cold cathode.*

The shape of the curves is the same as that demanded by theory, but they are slightly displaced towards the region of higher field strength (see positions relative to *a*). This is probably due to one condition of the theory not being fulfilled—that the free paths should be small compared with the distance between the electrodes. It would be expected that the discrepancy would be smaller with smaller electron-speeds and higher frequencies; this seems to be indicated by preliminary tests. More exact tests, with a gas pressure of about 0.05 mm., are being prepared.

Le Rôle des Électrons libres dans la Propagation des Ondes Courtes (The Part Played by the Free Electrons in the Propagation of Short Waves).—J. Granier. (*QST Franç.*, June, 1929, pp. 6–11.)

An article written round excerpts from recent letters and papers (dealt with in these Abstracts) by Störmer, Fabry, Ponte and Rocard, and Bureau.

Measurements of the Height of the Kennelly-Heaviside Layer.—G. W. Kenrick and C. K. Jen. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 711–733.)

Authors' summary:—In this paper we have sought to offer some further contribution to the Kennelly-Heaviside layer problem; first in the form of experimental data showing clearly evidence of the diurnal cycle in layer height, and secondly, in the form of a discussion of methods for the interpretation of group time and phase retardation experiments and the problem of determining the relationship between the "virtual" and "true" heights. Methods of successive approximation for arriving at the "true" height, from group time or phase retardation measurements, are also discussed and applied. Close accord is found between the results of these methods and the approximation used by Schelleng in a recent paper. The results shown in Fig. 16 also indicate the necessity for further experiments in the important frequency range from 1 to 4 megacycles where no data are available.

The Propagation of Electromagnetic Waves in a Stratified Medium.—D. R. Hartree. (*Proc. Camb. Phil. Soc.*, No. 1, 1929, V. 25, pp. 97–120.)

Author's summary:—The equations of propagation of electromagnetic waves in a stratified medium (*i.e.*, a medium in which the refractive index is a function of one Cartesian co-ordinate only—in practice the height) are obtained first from Maxwell's equations for a material medium, and secondly from the treatment of the refracted wave as the sum of the incident wave and the wavelets scattered by the particles of the medium. The equations for the propagation in the presence of an external magnetic field are also derived by a simple extension of the second method.

The significance of a reflection coefficient for a layer of stratified medium is discussed and a general formula for the reflection coefficient is found in terms of any two independent solutions of the equations of propagation in a given stratified medium.

Three special cases are worked out, for waves with the electric field in the plane of incidence, viz.:

(1) A finite, sharply bounded, medium which is "totally reflecting" at the given angle of incidence.

(2) Two media of different refractive index with a transition layer in which μ^2 varies linearly from the value in one to the value in the other.

(3) A layer in which μ^2 is a minimum at a certain height and increases linearly to 1 above and below, at the same rate.

For cases (2) and (3) curves are drawn showing the variation of reflection coefficient with thickness of the stratified layer.

Case (3) may be of some importance as a first approximation to the conditions in the Heaviside layer.

Chute d'un Gaz lourd dans un Gaz léger. Stabilité de l'Ozone dans la haute Atmosphère. (The Sinking of a Heavy Gas in a Light Gas. Stability of Ozone in the Upper Atmosphere).—Y. Rocard. (*Comptes Rendus*, 22nd May, 1929, V. 188, pp. 1336–1338.)

The author's calculations lead him to the conclusion that if the light gas is taken as being nitrogen, the rate of sinking of the ozone is 22 m. per day;

if hydrogen, the rate is 17 m. per day. In either case, the ozone is practically stable, and any fluctuations in the height of the ozone layer must be due either to the causes which create and destroy it or to general motion of the atmosphere.

OZONE DUE TO PARTICLES.—F. E. Fowle. (*Sci. News-Letter*, 1st June, 1929, p. 342.)

Of two layers of ozone in the earth's atmosphere, one (probably due to ultra-violet light) shows an annual period of change, depending on the position of the earth in its orbit; the other (perhaps due to the emission of particles shot out from the sun) shows a close relationship to sun-spots; probably, when these are at their minimum number, this second layer is absent entirely, though the observations have not continued long enough to ascertain this.

NOTE ON EARTH REFLECTION OF ULTRA SHORT RADIO WAVES.—E. H. Lange. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 745–751.)

Author's summary:—"In analytical investigations of the resultant pattern of electric intensity about an antenna, for the longer waves, the earth in the vicinity of the antenna has generally been considered as a perfect conductor. At sufficiently high frequencies, the reflected waves may differ considerably in magnitude and phase from perfectly reflected waves. The resultant distribution of electric intensity about an ultra short antenna depends upon the nature of the reflecting surface. Some computations and curves are given for the reflection coefficients and phase angles for various surface conditions, in conjunction with a horizontal ultra short antenna. Theoretical polar diagrams have been computed for various heights of horizontal antenna above the surface."

These polar diagrams agree well, in general form, with the experimentally observed distributions given by Yagi for waves of about 2.6 m. length (Abstracts, 1928, V. 5, p. 519).

GEOGRAPHICAL INFLUENCES AND RADIO WAVES.—R. Bureau. (*Nature*, 4th May, 1929, V. 123, p. 695.)

Summary of a paper in the *Revue Scientifique* for 23rd March, which would appear to cover much the same ground as the *Comptes Rendus* paper referred to in May Abstracts, page 262. Points mentioned here are:—apart from what happens in the upper atmosphere, important effects are produced in the troposphere, which is about six miles in height, and in the lower layers of the stratosphere. Contrary to expectation, direct experiment has shown that the surface which separates the stratosphere from the troposphere has little, if any, effect on the propagation of waves. It is found that short waves, whether entering or leaving France, have very different properties, which depend on their direction of propagation. Waves coming from the Caribbean Sea, Panama, and the Gulf of Mexico suffer little attenuation. On the other hand it is, if not impossible, at least very difficult to get signals from the North-East of the United States and from Newfoundland. Signals given by a 200-watt emitter on the Atlantic coast of Morocco seem never to reach Central or Eastern Europe, though they can be heard in other directions for thousands of miles. The radio waves seem to have difficulty in passing through the surface of separation between a mass of cold air and a mass of warm air. The lines which separate the audible zones from the zones of silence often coincide very closely with the meteorological lines separating masses of cold and warm air.

ENKELE OPMERKINGEN OVER DE ANALOGIE TUSSCHEN MECHANISCHE EN GOLFUITBREIDUNGSPROBLEMEN (Remarks on the Analogy between Mechanical and Wave-propagation Problems).—W. de Groot. (*Physica*, May, 1929, V. 9, No. 5, pp. 175–180.)

Author's summary:—It is shown that the Schrödinger expression for the dispersion of material waves,

$$u = \frac{h\omega}{\sqrt{2M(h\omega - V(x, y, z))}},$$

is the only one for which the velocity of wave-groups of any desired frequency can be represented by the motion of a particle in a potential field independent of frequency. It is therefore pointed out that in considering any dispersion law it may be useful to bring the dispersion formula, in a small frequency-range, into the Schrödinger form.

ÜBER DIE ACHSENSYMMETRISCHEN ELEKTROMAGNETISCHEN WELLEN MIT AXIALER FORTPFLANZUNGSRICHTUNG (On Axially-symmetrical Electromagnetic Waves Propagated in a Direction Parallel to the Axis).—N. S. Japolsky. (*Zeitschr. f. Phys.*, 21st March, 1929, V. 54, No. 1/2, pp. 108–122.)

Many workers have dealt with axially-symmetrical waves propagated radially—*i.e.*, perpendicularly to the axis of symmetry. The writer now deals with those waves propagated axially which he terms "axial waves," limiting his treatment to waves in an isotropic homogeneous medium. The paper is divided into the following sections:—Introduction; ordinary and "equi-phase" cylindrical co-ordinates; the general expression for the Maxwell differential equations and its application to axial waves; the differential equations of simple harmonic cylindrical waves, and their integration; the calculation of the radial complex factors; the transition from cylindrical to conical waves; concluding remarks on the importance of these waves.

ÜBER DIE FREQUENZÄNDERUNG DES LICHTES DURCH VARIATION DES OPTISCHEN WEGES (On the Frequency Change of Light Due to Variation of Optical Path).—S. Levy. (*Zeitschr. f. Phys.*, 11th May, 1929, V. 54, No. 9/10, pp. 674–675.)

The writer takes as an example the passage of a ray of monochromatic light through a Kerr cell supplied with periodically varying potential, and investigates the consequent frequency difference between the two components (the waves parallel to and perpendicular to the electric field). The bearing of this result on Rupp's experiment on the modulation of a light ray is discussed (Abstracts, 1928, V. 5, p. 587.)

SUR LA CONSTANCE DE LA VITESSE DE LA LUMIÈRE (On the Constancy of the Velocity of Light). —P. Salet. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1539–1540.)

"The study of double or variable stars has shown that the velocity of light is—so far as can be observed—independent of wavelength (dispersion in space) and of the motion of the source (ballistic theory). The question arises whether it may be modified by other causes, notably the attraction of the source. In the case of a Newtonian attraction, light proceeding from a star with velocity *c* would quickly assume a slightly smaller velocity. The loss of velocity, about proportional to the ratio mass/radius of the star, would amount to 0.7 km. per sec. for the sun, and would change with the spectral type." The writer suggests that observations on double spectroscopic stars would furnish a test as to the existence of such variation.

A METHOD OF EXPLORING THE ATMOSPHERE BY THE HELP OF DISTURBANCES OF ELECTROMAGNETIC FIELD AT THE PASSAGE OF THE TWILIGHT BAND.—J. Lugeon. (*See* under "Atmospherics.")

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

SUR L'ORAGE MAGNÉTIQUE DU 7 AU 8 JUILLET 1928 ET LES PHÉNOMÈNES CONNEXES (The Magnetic Storm of 7th–8th July, 1928, and its Associated Phenomena).—Ch. Maurain. (*L'Onde Élec.*, April, 1929, V. 8, pp. 170–172.)

Information from various sources, sent to the writer as a result of his former note on this storm (Abstracts, 1928, V. 5, p. 638), is given here. At Spitzbergen, variations of 5 degrees in the magnetic declination were noted, and reception of short waves (30 m.) showed great weakening or complete cessation, whereas 600 m. and 9–18 thousand metre waves showed no weakening. A few sunspot and polar aurora observations are included.

SUR L'ORIGINE DE CERTAINS PARASITES (On the Origin of Certain Atmospherics).—Ch. Maurain. (*L'Onde Élec.*, April, 1929, V. 8, pp. 131–134.)

Author's summary :—"The similarity between the diurnal variation of the earth's magnetic agitation and the diurnal variation of one category of atmospherics [nocturnal] suggests the idea of a relation between the two phenomena. A recent work of T. L. Eckersley shows such a relation ["whistlers"—January Abstracts, p. 38]. The diurnal and annual variations of storms, on the other hand, are similar to those of a second category of atmospheric ["afternoon" atmospherics] which would appear to originate in storm-phenomena; the comparison of storm frequency charts with charts of these atmospherics would be capable of throwing light on the range of the latter, which is much disputed. . . ."

The writer supports Bureau (*ibid.*, 1926, p. 301) in his rejection of "certain interpretations supposing, without sufficient proofs, that a certain atmospheric is the result of a certain atmospheric discharge at some more or less great distance"; but he considers that Bureau does not pay sufficient attention to the relation between storm phenomena (of which lightning is one manifestation) and atmospherics. He quotes a table of storm statistics giving, for the whole of France, the average proportion of storms per month taken over 33 years, showing the enormous increase in summer (15.6 to 19.02 as compared with 1.04 in January), and compares this with Bureau's statement that in temperate regions the afternoon atmospherics are always more prominent in summer than in winter.

SUR L'ORIGINE DE CERTAINS PARASITES.—R. Bureau. (*Ibid.*, pp. 134–142.)

A reply to the above. The writer agrees that the afternoon or "stagnant" atmospherics are, like storms, an effect of stormy meteorological conditions, but he lays stress on the point that they are *not* an effect of "storms strictly so-called"—*i.e.*, lightning flashes.

As regards nocturnal atmospherics, on the other hand, he disagrees with Maurain. Even if he admits the possibility of a relation between atmospherics and magnetism, he insists that the relation is not a simple one and that in all cases a vigorous meteorological action is superimposed on it. He gives four principal reasons for this belief :—(1) the nocturnal atmospherics disappear above the layers of inversion (an effect noted by Lugeon and recently confirmed by the writer by comparison of the records of Mt. Valérien and St. Cyr); (2) the amplitude and number of these atmospherics are very variable; this variation is in close relation with the meteorological situation (records are given, taken at St. Cyr in December, 1928); (3) magnetic storms do not appear to be accompanied by a "recrudescence" of atmospherics: in particular he cites the storms of 26th January, 1926 and 7th July, 1928; and (4) the minimum of atmospherics takes place about 8 o'clock in winter, but in summer it occurs earlier and always about sun-rise. Maurain and Eblé have themselves shown that the daily minimum of magnetic disturbance is displaced in the opposite sense and approaches mid-day in summer.

The last part of the paper is devoted to an exposition of how all three classes of atmospherics can ultimately be attributed to meteorological factors—the vertical thermal instability of the atmosphere and the convection currents resulting from it. When the atmosphere is stratified in a stable way and, in consequence, there is no exchange between the various superposed layers, the distribution of potential is equally stable and there is no cause for the existence of appreciable horizontal gradients between two points on the same level. Such a condition, free from atmospherics, is formed in spring and autumn in the masses of tropical air in temperate regions. When, however, vertical ascending and descending movements set in, particles of air from very different levels find themselves at every moment brought to the same level and very close to each other; thus at every point, at every instant, comparatively high horizontal electric gradients are formed. This effect is the stronger, the weaker the horizontal currents. In the case of a turbulence of uniformly distributed movements of small amplitude, discharges would

be fairly small but very numerous and almost continuous (nocturnal atmospherics); in the case where powerful movements occur alternately up and down (stormy Cu. Nb., strong cold fronts) there would be more violent discharges, perceptible over quite extended regions but grouped irregularly in time ("cold front" atmospherics). The writer concludes by remarking that observations of the aerial-earth current or of the "whistlers" mentioned by Eckersley should give valuable information on the variations of vertical electric gradient, just as observations of atmospherics give information on the horizontal gradients.

A Method of Exploring the Atmosphere by the help of the Disturbances of Electromagnetic Field at the passage of the Twilight Band.—J. Lugeon. (*Comptes Rendus*, 22nd April, 1929, V. 188, pp. 1114–1116.)

In anti-cyclones in particular, stratified zones of inversion of temperature exist at a mean altitude which varies from a maximum exceeding 2,500 metres in August, to a minimum of some 700 metres in February over the Swiss plateau. Though this layer is thermally stable, its electric state has a very important daily variation which is the direct product of solar radiation. This variation produces at dawn a very rapid diminution or disappearance of atmospherics, while re-establishment of the régime of nocturnal atmospherics in the evening occurs more slowly. The layer thus possesses a nocturnal post-twilight electromagnetic inertia which seems to be a function of the variation of diurnal illumination and to a certain extent of the intensity of this radiation, which itself depends on the purity and temperature of air masses above the layer. If frontal cirrus or the margin of a cloud system cut off the solar rays for an instant, atmospherics will begin more rapidly after sunset, but they will be weaker than in cases where the sky remained clear throughout the day. The examination of the diagram of atmospheric disturbance thus permits the detection, from under the sea of mist, of the presence of clouds above it invisible to the eye. These conclusions apply specially to local atmospherics, but they refer also to distant atmospherics which have marked directional properties and which continue unchanged into the daylight phase in contradistinction to the local atmospherics.

With the help of curves recording the frequency of incidence of atmospherics, there can be calculated the height and thickness of the sea of mist and of all other stratified cloud ceilings possessing the same electromagnetic properties, as for example certain cirrus layers, some dry haze layers, ionised regions, and the so-called Heaviside layer. At the precise instant when the rays of the rising sun penetrate one of these screens, there is produced on the diagram a very sharply marked maximum (due to the screen acting also as a source of local atmospherics), followed by a progressive diminution in frequency and in intensity of atmospherics. The analysis of numerous special cases of the last nocturnal maximum of atmospherics thus allows a diagnosis to be made, not only of the troposphere but also of the stratosphere, and a calculation of the altitude of the Heaviside layer. This layer, whose thickness would appear to be between 5 and 30 km., seems to be subject to a true tide independent of its daily oscillation with a period lying between 9 and 12 days. The amplitude of this tide seems to vary somewhat slowly between the altitudes of 70 and 150 km. The author finds evidence of one layer varying between the heights of 250 and 750 km. He finds also a peculiarity in the record during the morning astronomical twilight which he interprets as implying the existence of a thick layer of inversion of temperature oscillating between the altitudes of 31 and 62 km., probably the ozone layer, where—according to recent experiments on the propagation of sound waves—the temperature would appear to reach that of the human body.

Houlton Observations on the Direction of Atmospherics.—A. E. Harper and S. W. Dean. (*Sci. News-Letter*, 25th May, 1929, V. 15, pp. 327–328.)

Addresses to the I.R.E. "It is sometimes assumed that static is of relatively local origin and is rapidly attenuated along its path. This theory seemed to us rather untenable, since simultaneous records have been made of static crashes at Hawaii, New York, and Germany. We believe that for receiving in Maine the most important source of static is thunderstorms in the U.S. and Canada, after which we put thunderstorms in other portions of the globe. In addition to actual thunderstorms we find static accompanying weather disturbances such as electrified clouds, etc., which have not reached the point of producing audible thunder. As a working hypothesis it may be assumed that such static is produced on the south-east edge of an advancing low-pressure area, especially if precipitation occurs. This condition when accompanied by up-rushing winds, according to Dr. W. J. Humphreys of the U.S. Weather Bureau, tends to produce a thunderstorm. Therefore in the absence of other data, thunderstorm charts would be the most logical index of the location of static sources. This theory seems to be strengthened by our Houlton measurements."

From cathode ray oscillograph records, places as far remote from Maine as Florida, Africa, a position at sea off Argentine, Southern Mexico, Ecuador and Brazil are all responsible for some of the static that interferes with the telephone service. All these are recognised as great thunderstorm centres.

S. W. Dean mentioned that in the summer the effects of near-by disturbances usually overshadow these distant sources. A low-pressure area seems to produce more atmospherics when it is moving rapidly. When it is more or less stationary or quiescent it produces few atmospherics. In the summer, low-pressure areas produce many more atmospherics when over land than after they pass out to sea, but in cool weather the reverse is sometimes true. He then dealt with the prediction of approaching storms by observations on atmospherics. "It would seem that as few as three stations, one on the north Atlantic coast, one on the south Atlantic coast, and one in the middle west, would cover the eastern part of North America and the western part of the Atlantic Ocean fairly well. Our experience indicates that such a system might be helpful in the location of storms in northern

Canada, the Atlantic, the Gulf of Mexico, and the West Indies, as well as those in the eastern half of the United States."

DISTRIBUTION OF TEMPERATURE IN THE FIRST 25 KILOMETRES OVER THE EARTH.—K. R. Ramanathan. (*Nature*, 1st June, 1929, V. 123, pp. 834–835.)

The writer gives a diagram showing the probable distribution (using all the data now available) of isotherms in the atmosphere up to 25 km., in summer and winter over the Northern Hemisphere. He summarises the principal features; gives a second diagram illustrating the seasonal variation of temperature of the tropopause at Batavia and Agra, and quotes Bemmelen's figures for the variation of height of the tropopause over Batavia, similar to that occurring over Agra but displaced by about 6 months. "The lower temperatures and greater heights of the tropopause in summer are presumably due to the stronger convection in the troposphere in that season. The persistent increase of temperature with height for at least 5 km. above the tropopause in the tropics finds a natural explanation if we assume that the tropopause marks the lower limit of the ozone layer in the atmosphere."

THE IMPORTANCE OF LINES OF EQUAL ENTROPY IN ATMOSPHERIC PHYSICS.—Napier Shaw. (*Nature*, 15th June, 1929, V. 123, p. 906.)

Referring to Ramanathan's letter (see above) the writer mentions the desirability of a corresponding diagram, embodying all the data available, of the lines of equal entropy: pointing out the important influence of entropy on convection and therefore on weather:—"it is entropy which decides the equilibrium position of a sample of air, whether it will rise or sink or stop where it is. . . Circulation along an isentropic surface can take place without any communication of heat, no matter whether the controlling surface be horizontal or vertical at the position of the sample. . . ."

THE MOTION OF IONS IN CONSTANT FIELDS.—Leigh Page. (*Phys. Review*, April, 1929, V. 33, pp. 553–558.)

Author's abstract:—It is shown that the effect of constant electrical or gravitational force F on ions passing through a constant magnetic field H is to cause the circular or helical ion paths to advance in a direction at right angles to both F and H with the constant velocity $u = c\,[\mathbf{F} \times \mathbf{H}]/eH^2$. Ion paths relative to a rotating earth are discussed on the assumption that the earth's field is purely magnetic relative to the inertial system of the centre of the earth. The essential features of the theory are shown to be unaltered if the constant mass of the classical theory is replaced by the variable mass of the relativity theory.

SONDAGES DE PRESSION ET DE TEMPÉRATURE PAR RADIOTÉLÉGRAPHIE (Pressure and Temperature Soundings by Radiotelegraphy).—R. Bureau. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1565–1566.)

A description of the writer's use of automatic transmission by wireless of the readings of a barometer and a thermometer carried in an exploring balloon in its ascent into the stratosphere.

In the case of a thermometer with a range from +20 to −60°C., the error is less than 0.7°, and this can be reduced by reducing the range of temperature. The system gives a valuable saving of time over other methods (aircraft, ordinary sounding balloons) for the analysis of meteorological conditions and for forecasting weather. The readings are given by the length of the signal dashes compared with the intervening spaces.

NEW EVIDENCE OF THE ACTION OF SUNLIGHT ON AURORA RAYS.—C. Störmer. (*Nature*, 8th June, 1929, V. 123, pp. 868–869.)

Further work on the subject referred to in April Abstracts, p. 204. A new phenomenon has been observed, certain of the high sun-lit rays having extensions in the dark zone, the connecting portion (beginning at the sunlight boundary and extending downwards a little way) being invisible.

THE SUN'S RADIAL MAGNETIC GRADIENT AND ATMOSPHERE.—Ross Gunn. (*Phys. Review*, April, 1929, V. 33, pp. 614–620.)

Theory of the radial magnetic gradient of the sun based on the diamagnetic effect produced by ions spiralling about the impressed magnetic field. Ionic densities estimated from magnetic data.

AN ELECTROMAGNETIC EFFECT OF IMPORTANCE IN SOLAR AND TERRESTRIAL MAGNETISM.—Ross Gunn. (*Phys. Review*, May, 1929, V. 33, pp. 832–836.)

Author's summary:—"*The thermal motions of ions in an inhomogeneous magnetic field give rise to a systematic ion drift.* A study of the motions of ions executing long free paths and spiralling about an inhomogeneous impressed magnetic field has shown that a systematic drift is imposed which is oppositely directed for the positive and negative ions. The resulting drift velocity is proportional to the component of the magnetic gradient that is perpendicular to the magnetic field itself. Under the conditions of radial symmetry and a closed circuit a current flows which is in such a direction as to reduce the inhomogeneity of the impressed field and to increase the total flux enclosed by the current circuit. This increase in the flux enclosed by the circuit shows that the phenomena may be regenerative. Certain applications to the sun's atmosphere, sunspots and the permanent magnetic field of the sun and earth are suggested."

One of these applications leads to the supposition of the existence in the sun's atmosphere of *westward* currents which, if not compensated, would greatly increase the apparent magnetic moment of the sun; using available data and certain assumptions, the calculated magnetic moment of the westward current sheet turns out to be about the same as would be computed for a sun represented by a uniformly magnetised sphere of polar strength 50 gauss; suggesting that the permanent magnetic field of the sun and earth is due to similar phenomena taking place probably in the interior where the free paths of the ions are short. "The ion density selected for the above calculation seems too low by

one or two orders of magnitude and we are led to believe that diamagnetism and perhaps *eastward* currents play an important part in solar magnetism, since the larger densities would lead to values of the magnetic moment which were much too large." It is suggested that the eastward gravitational current dealt with by Chapman and the westward "magnetic gradient" current here described would largely neutralise each other, since a calculation of the latter—using Chapman's data—gives a velocity of drift of both ions approximately equal to Chapman's value for the gravitational drift velocity.

EFFECT OF THE EARTH'S MAGNETIC AND ELECTRIC FIELDS ON ION PATHS IN THE UPPER ATMOSPHERE.—Leigh Page. (*Phys. Review*, May, 1929, V. 33, pp. 823–831.)

Author's summary:—"It is shown that the lines of force of the earth's magnetic field can be treated as if rotating with the earth in so far as the calculation of ion paths is concerned only if there exist positive charges over the poles accompanied by negative charges over the equator. The earth would have a total charge of −72 coulombs although observers on the earth would be aware of no electric field. Assuming that the earth is an uncharged, conducting, uniformly magnetised sphere, rotating about its magnetic axis with angular velocity Ω, it is shown that ion paths progress to the west, the velocity of progression increasing with altitude so as to approach the limiting value $-\Omega \times r$ which measures the progression that would exist if the earth's field were solely magnetic relative to observers who do not partake of the rotation. The earth would have an *apparent* charge of $+72$ coulombs although actually uncharged. It is shown that a uniformly distributed charge q on the earth merely changes the value of the limiting westward velocity found above, increasing the westward progression if q is positive, and decreasing it if q is negative."

PROPERTIES OF CIRCUITS.

ÜBER DIE MAXIMALLEISTUNGEN VON SCHUTZNETZLEISTUNGSRÖHREN (On the maximum Output of Screen-Grid Power-amplifier Valves).—H. Bartels. (*E.N.T.*, May, 1929, V. 6, pp. 182–193.)

Further development of the work referred to in July Abstracts, p. 388. By calculation and from experimentally measured characteristic curves of screen-grid power-amplifier valves, the writer shows that for equal anode loads and approximately equal battery voltages the attainable A.C. output for the screen-grid valve is equal to that of the corresponding single-grid valve. For powers of several watts and over, the single-grid valve is preferable ["the screen-grid valve is more sensitive to mechanical shocks. . . . If screen-grid valves are to be used it would seem more advantageous to employ them in the earlier stages as voltage amplifiers"]: for smaller powers [*e.g.*, where the audion valve controls the power valve directly] the screen-grid valve may be advantageously used for the sake of its saving in grid potential [especially when, for as small grid-voltages as possible and for a given type of loud-speaker, it is desired to maintain a constant ratio of grid voltage to anode current.] Finally it is shown that quite generally the highest obtainable ratio of A.C. output to the maximum anode load has the limiting value 0.5 for all types of valves and all methods of loading.

DETECTION CHARACTERISTICS OF SCREEN-GRID AND SPACE-CHARGE-GRID TUBES.—F. E. Terman and B. Dysart. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 830–833.)

A paper giving data on the grid-leak detection characteristics of four-electrode valves, in continuation of a similar study of triodes (May Abstracts, p. 273). Results are expressed in terms of the detector voltage constant v as a function of grid resistance, and are obtained from bridge measurements of dynamic grid resistance at grid voltages that differ slightly. It is found that the rectifying properties of the grid circuit for the four-electrode valve, used in screen-grid or space-charge-grid connection, are about the same in character and magnitude as in triodes with the same type of filament. The rectifying action in the grid circuit is largely independent of the voltages of filament, plate and second grid when compared at the same grid resistance. The space-charge-grid-leak-condenser detector is superior to the screen-grid and most triode grid-leak-condenser detectors, in that the space-charge-grid valve retains its full rectifying powers at adjustments which give full reproduction of the high notes.

VERSTÄRKUNGSMESSUNGEN AM RÜCKGEKOPPELTEN WIDERSTANDSVERSTÄRKER. KONSTRUKTION EINES KOMPENSIERTEN VERSTÄRKERS MIT GERADER FREQUENZKURVE (Amplification Measurements on the Reactively-coupled Resistance Amplifier. Construction of a Compensated Amplifier with Straight-line Frequency Characteristic).—H. G. Baerwald. (*Arch. f. Elektrot.*, 8th May, 1929, V. 22, No. 1, pp. 81–103.)

A resistance amplifier with strong reaction by ohmic resistance is neither linear nor independent of frequency in its working. Investigations (such as those described in this paper) into the frequency-dependence of such an amplifier must be based, therefore, on keeping the output voltage constant and measuring the various inputs. The constant output voltage was chosen so large that the amplifier worked as an "amplifier limiter" (L. B. Turner). Various precautions necessary for the measuring process are described—*e.g.*, the neutralisation of interfering stray voltages, screening, etc.—and the probable errors are discussed. The next section deals with the experimental and theoretical investigation of the "uncompensated" resistance amplifier and its behaviour; theoretical and experimental curves agree well. "Quasi-resonance" (involving capacitive and ohmic elements only, without inductance) is discussed, and its dependence on the reaction-amplification constant.

The above work leads up to the development of a "compensated" amplifier with a straight line characteristic (in the case in point) between 3,000 and 35,000 cycles per sec. The lower limit can be reduced without difficulty. A 2-valve amplifier on

this design allows a reaction-amplification of 73 (*i.e.*, an absolute amplification of about 8,500) with practically complete frequency-independence, compared with a value of about 9 for the amplifier without compensation. The compensation is obtained by the use of a complex reaction resistance made up of (adjustable) ohmic resistances in series and parallel with an inductance. The parallel connection was apparently necessary because H.F. oscillations were set up by the series inductance-resistance arrangement; this trouble was stopped by the parallel (several thousand ohms) resistance.

THE PROBLEM OF "TURN-OVER."—M. Reed. (*E.W. & W.E.*, June, 1929, V. 6, pp. 310–315.)

Under certain conditions the value of the current obtained in the plate circuit of a rectifying tube, for a given A.C. input, is not the same if the connections to the input of the rectifier are reversed. The ratio of the two values of the plate current is known as the "turn-over," and the conditions under which it is obtained are here considered and the results applied to the case of the ordinary valve-voltmeter and to the valve-voltmeter using the "slide-back" principle. It is shown that (1) in both types there will be an error due to "turn-over" if the applied voltage wave contains suitable harmonics and if the equation of the rectifier characteristic is at least a cubic; (2) the error will become less as the value of the negative grid bias on the rectifier is decreased; (3) to avoid error due to "turn-over" it would be necessary (*a*) to make the input free from harmonics; (*b*) to employ two valves to form a balanced rectifier; (*c*) to employ a rectifier whose characteristic can be expressed by a quadratic over the operating portion; or (*d*) to determine the value of the grid bias so that the operating point is in a region where the rectifier characteristic can be expressed by a quadratic, and to arrange that the input to the rectifier is such that the grid swing does not go beyond this region.

EINE BEOBACHTUNG BEI VERSUCHEN ZUR BESTIMMUNG DER FREQUENZMODULATION VON RUNDFUNKSENDERN (A Point Noticed in Tests to determine the Frequency Modulation of Broadcasting Transmitters).—F. Gerth and W. Scheppmann. (*E.T.Z.*, 16th May, 1929, V. 50, p. 722.)

It was found, by a slow repetition of the modulation characteristic, that an oscillating audion close to the transmitter gave a marked change in heterodyne note between the points of maximum and minimum aerial current—in the case in point, a total frequency change of 0.3 per thousand being found. The same effect was noticed with the same receiver at a distance of 10 km., when used with a vertical aerial; but when used with a closed oscillating circuit, no such frequency change was found. The conclusion is that the effect of strong signals on the oscillating audion is to alter its natural frequency by displacing the working point on the curve; for successful measurements, therefore, care must be taken not to load such a receiver heavily; loosely coupled circuits or—better still—a quartz controlled oscillator are recommended. Tuning the whole receiver to a high harmonic would also give accurate results.

FREQUENCY MULTIPLICATION BY SHOCK EXCITATION.—E. A. Guillemin and P. T. Rumsey. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 629–651.)

Authors' summary:—The fundamental principles involved in the theory of frequency multiplication by means of iron-core coupled circuits are briefly reviewed from the standpoint of Fourier analysis as well as that of recurring transients. Oscillograms and figures illustrating the effect of transformer inductance and shock duration upon wave form are given. Oscillations of the first and second kind are discussed in their relation to the analogous arc circuit problem. Efficiency and power output are considered in their dependence upon primary and secondary current amplitude, and the conditions for smoothest wave form and maximum efficiency are pointed out.

TRANSFORMERS AS BAND PASS FILTERS.—E. K. Sandeman. (*Elec. Communication*, April, 1929, V. 7, pp. 282–292.)

PRINCIPLES OF GRID-LEAK GRID-CONDENSER DETECTION (F. E. Terman): Discussion.—(*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 752–754.)

The paper was dealt with in January Abstracts, p. 41. Polydoroff argues from Terman's conclusions that for the best results the detector constants should be adjustable, and mentions that he has found a very practical method of control of detector load to be the use of the old variable grid-leak. The variable leak (15,000 to 500,000 ohms) is in parallel with a fixed 2-megohm resistance. When "off," the variable leak leaves the detector adjusted to maximum sensitivity for weak signals, with its 2-megohm leak; while for louder signals it can be suitably adjusted to give the best results.

TRANSMISSION.

THE SHORT-WAVE LIMIT OF MAGNETRON OSCILLATIONS.—K. Okabe. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 652–659.)

The writer explains the process in the magnetron as follows:—when the magnetic field is greater than the critical value, the anode current is cut off and there is an accumulation of charges near the anode and cathode. The accumulation of charges near the anode is the true seat of oscillatory phenomena. As soon as the conditions become such that a negative resistance is possible, the accumulated charges begin to be dispersed or discharged and the state of negative resistance disappears until a further accumulation of charges occurs. The time required for such accumulation after the preceding discharge is approximately equal to the time t taken by an electron to travel from the cathode to the region near the anode where the charge density is greatest. The period T of the resulting oscillations will be $T = t + t'$ where t' represents the time required for the electronic discharge. We have at present no way of estimating t', but since the process is alternating, the writer considers it not unreasonable to assume that t' is approximately equal to t. From this he arrives at an equation for

the wavelength $\lambda = \frac{2\pi c^2 m}{eH} = \frac{10650}{H}$ cm., whereas experimentally $\lambda = \frac{13000}{H}$ cm.

The former equation was a simplification made by assuming the radius of the cathode to be extremely small, which would account for the difference of about 20 per cent. between theory and experiment.

Theoretically, therefore, if H could be raised to 20,000 gauss a wavelength of 6.5 mm. would be obtained. But there is another condition to be complied with :—the maximum oscillation (generally) occurs in the neighbourhood of the critical field strength, and consequently the following relation should exist—

$$\text{anode radius } r_a = \sqrt{\frac{8mc^2}{H^2 e} \cdot V_a} = \frac{6.7}{H} \sqrt{V_a} \text{ cm.}$$

Now assuming an anode voltage of 10,000, the anode radius would work out at 0.34 mm., and it is doubtful whether such conditions could be fulfilled. But it would appear that the practical lower limit of wavelength is of the order of a few millimeters. The shortest actually produced so far is 5.6 cm. (neglecting harmonics).

A Study of the Three-Electrode Vacuum-Tube Oscillator.—Conditions for Maximum Current.—E. T. Cho. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 1038–1049.)

This study is confined to the "tuned-grid" circuit. Experimental results plotted as curves bring out the fact that there is a simple relation of the inductance L to the capacity C of the tuned grid-circuit, when the constants of the oscillating circuit have been adjusted to give the largest possible current. This relation depends upon the filament and plate potentials and the resistance of the circuit, thus :—L/C varies as $1/E_f$, as R, and as E_p; or $L = hRE_pC/E_f$, where h is a constant which for the valve used (type 201 A) was about 50. The value of C is much larger than that usually employed in practice (the results apply for maximum current and not necessarily for maximum power or efficiency). Another relation found experimentally is that if M is the mutual inductance between L and the anode-circuit reaction-coil, for maximum current M/L is a constant; this holds good for circuit tuning from 50 to 1,600 metres. The average value found for this constant is 3.3. Theoretically, it is shown that the ratio M/L for maximum current should equal about half the amplification constant, *i.e.*, for the particular valve used, it should equal about 4.5.

Short Wave Generation.—(German Patent 471524, Žácek, published 14th February, 1929.)

Žácek's 1924 patent using the effect of a magnetic field on the electrons as they emerge from the cathode : this field is parallel to the cathode and causes the electrons to describe spiral-shaped curves round the cathode, in planes perpendicular to the field. The resulting oscillations depend for their frequency on the strength of field, the electrode voltages and the electrode distances.

Sur les Ondes de 10 à 20 Centimètres (10–20 cm. Waves).—G. Beauvais. (*Bull. d. l. Soc. franç. d. Élec.*, May, 1929, V. 9, pp. 503–510.)

See June Abstracts, p. 326. In the present article diagrams are given of the Pierret transmitter and receiver circuits, of the super-regenerative receiver used in the writer's tests, and of the Pierret circuit adapted to telephony.

Telegraphy Control with Valve Idle Load.—(German Patent 471895, Telefunken, published 19th February, 1929.)

The grid circuit of the transmitting valve contains a resistance which is also included in the grid circuit of the valve forming the idle load. The change of transmitting valve grid-current, when the anode supply is connected by closing the key, thus affects the grid of the idle-load valve and prevents it from taking its load.

L'Alimentation des Postes Émetteurs Radio-électriques à Bord des Avions (Current Supply for Aircraft Radio Transmitters).—J. Morel. (*L'Industrie Élec.*, 25th February, 1929; summary in *Génie Civil*, 8th June, 1929, V. 94, p. 563.)

RECEPTION.

Die aperiodische Verstärkung von Rundfunkwellen (The Aperiodic Amplification of Broadcast Waves).—M. v. Ardenne. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 166–175.)

The author considers that for frame-aerial reception, the average necessary R.F. amplification lies between five and ten thousand. Four triode stages are needed for this, and if tuned amplifiers are used (*i.e.*, 5 tuned circuits) adjustment becomes complicated or the apparatus expensive (gang control) : moreover, loss of quality is probable owing to too much selectivity. Screen-grid valves, with their 25–40 amplifications between 200–600 m., get over some but not all of this difficulty. Aperiodic amplifiers solve it completely. Such amplifiers, capable of useful amplification in the wave-range named, were known in 1927; but the valves of those days, when thus used, had certain failings (too high a current-consumption in the space-charge circuit, and L.F. disturbances due to L.F. amplification accompanying the R.F. amplification). The writer therefore deals with the design of up-to-date aperiodic amplifiers for the latest valves.

Discussing the choice between resistance, choke, and transformer coupling, he concludes that for the sake of obtaining independence of frequency over the wide range in question, without reducing the amplification per stage by having to choose a valve with low internal resistance, resistance coupling is preferable. The rest of the paper, therefore, deals with this type only. Treating first the preliminary calculation of a single stage, the writer compares his mathematical results with data of the recently-developed Loewe 2 H.F. single-grid valve, showing how well these valves fit in with the best conditions for the wavelengths in question.

Two possible methods for obtaining the greatest possible amplification are given as (*a*) diminution of the effective capacity and (*b*) increase of the valve constant. One way of accomplishing (*a*) is to design so that the electrode and internal structure capacities are kept small—as can be done so successfully in multiple valves; the other way is to keep down the effective capacity by eliminating (by compensation) the apparent capacity due to anode reaction—a plan which was unfavourably criticised in a former work (Abstracts, 1928, V. 5, pp. 402 and 466). As regards (*b*), attempts have been made to use high-emitting cathodes by employing several filaments in parallel, but this plan is bound to increase the inter-electrode capacities. Indirectly heated cathodes, however, work well in multiple valves. The rest of the paper deals with combination of units into a cascade, starting with general considerations and going on to the use of the 2 H.F. multiple valves previously referred to. In this new type the makers have given up the space-charge grid, partly because the full advantage is not obtained in H.F. resistance-coupled amplifiers, partly because of the smaller capacity of the single-grid system.

RADIO FREQUENCY TRANSFORMERS AS APPLIED TO SCREEN-GRID VALVES.—S. Butterworth. (*E.W. & W.E.*, June, 1929, V. 6, pp. 293–299.)

When the screen-grid valve was introduced it was hoped that the inter-electrode capacity would be reduced to such a value that efficient recording circuits could be employed to give stable systems having high magnifications, without the need for the "somewhat delicate operation" of neutrodyning. By using screen-grid valves of a special construction, Hull and Williams reduced the capacity to 0.006 $\mu\mu$F. as compared with the 2 $\mu\mu$F. or more of the ordinary triode; but the commercial screen-grid valve usually has a value of 0.05 to 0.1 $\mu\mu$F. (*cf.* Bligh, these Abstracts, under "Valves"). The writer therefore sets out to find how to make the best use of R.F. transformers while accepting capacities of this order, and without the use of neutrodyning (see Sowerby, June Abstracts, p. 329).

His investigation leads to the conclusion that the best method is to use a transformer in which the primary turns are reduced until the requisite stability is attained. The transformer ratio required will vary inversely as the square root of the frequency of instability, while the expected magnification will vary in like manner. For multi-stage amplification, the procedure indicated can be applied; but in this case the writer is inclined to prefer the plan of interleaving transformer- with resistance-capacity-coupling, so as to reduce the possibility of instability owing to capacity coupling between the tuned circuits.

MORE AMPLIFICATION FROM SCREEN-GRID VALVES.—(*Wireless World*, 12th June, 1929, V. 24, p. 623.)

In a recent article under this heading (June Abstracts, p. 329) figures were given for the theoretical amplification attainable on the broadcast band using the Cosmos AC/S valve in conjunction with a special tuned circuit of high dynamic resistance. These figures were based on measurements made on an advance sample of the valve, which appears to have been by no means up to the standard of those now on the market; with these, an amplification of well over 500 times has been actually measured, with no assistance from reaction, at 300 m.

THE DESIGN OF H.F. TRANSFORMERS: PART I.—THE ESSENTIAL THEORY CONCERNING THE INTERDEPENDENCE OF VALVE AND TRANSFORMER. PART II.—SOME EXPERIMENTAL DATA.—A. L. M. Sowerby. (*Wireless World*, 29th May and 12th June, 1929, V. 24, pp. 548–552 and 617–621.)

"In conclusion, we may say that the simple theory of the high frequency transformer presented in the first of these articles is well borne out in practice at every point at which it has been tested by experiment, and that the inaccuracies imported into it by the simplifying assumption of infinitely close coupling are negligible, at least with the type of winding adopted. We may, therefore, use the equation $n = \sqrt{\frac{R}{R_0}}$ for determining the ratio for any transformer of which the secondary characteristics are known. Having found the ratio n, either by calculation or by the method of measurement described, we can take $A = \frac{1}{2}\mu n$ as a reliable estimate of the amplification to be expected from the stage when transformer-coupling is used in a high-frequency amplifier."

IMPROVING DETECTOR EFFICIENCY.—W. B. Medlam.—(*Wireless World*, 22nd May, 1929, V. 24, pp. 524–528.)

It is generally considered that an anode-bend detector has but a slight reaction on the R.F. input circuit to which it is coupled, assuming that the operating conditions are such that there is no grid current. Attention is here drawn, however, to the load due to R.F. feed-back through the anode-grid capacity of the valve, which may reduce the signal voltage, under certain working conditions, by more than fifty per cent. Suggested remedies are:—(1) the use of a centre-tapped input circuit and a neutralising condenser; (2) a series tuned circuit (tuned to the carrier frequency) connected across the external anode lead, serving to exclude H.F. potentials from the 1st L.F. amplifier grid; this means an additional tuning control but is very effective; and (3) the use of a pentode, with its excellent rectifying properties; no details are given as to this solution.

A SELECTIVE 8-VALVE RECEIVER FOR MEDIUM AND LONG-WAVE TELEGRAPHY.—F. M. Colebrook. (*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 177–183.)

Author's abstract:—"The receiver here described was designed for the Metrology Department of the National Physical Laboratory, for the reception and recording of time signals on wavelengths ranging from 1,500 to 20,000 metres. The principal requirements were: (*a*) comparative ease of manipulation; (*b*) sufficient sensitivity and selectivity for the signal operation of a relay for

recording purposes. The latter requirement is a severe one as far as the long-wave range is concerned. The receiver consists of four separate parts: (*a*) aerial tuning and coupling unit; (*b*) 4-valve amplifier (2 radio-frequency amplifying stages, detector, and 1 audio-frequency amplifying stage); (*c*) local oscillator; (*d*) selective audio-frequency amplifier. A detailed description is given of each of these parts."

As set up at the National Physical Laboratory, with a single wire aerial some 50 ft. high and 130 ft. long, the receiver gives Annapolis (NSS) without difficulty, an anode-current change of about 1 to 1½ mA. being obtained.

DER SABA-KURZWELLEN-EMPFÄNGER (The "Saba" Short Wave Receiver).—H. Gunther. (*Rad., B., F., f. Alle*, June, 1929, pp. 280–288.)

A three-valve receiver with five interchangeable coils giving wave-ranges of 13–25, 25–45, 40–90, 200–440 and 440–950 metres.

BROADCAST RECEIVERS—PHILIPS TYPE 2802. A FOUR-VALVE SET FROM 10 TO 2,400 METRES. —(*Wireless World*, 22nd May, 1929, V. 24, pp. 542–543.)

THE MODERN PORTABLE, A REVIEW OF CURRENT COMMERCIAL PRACTICE. REPRESENTATIVE PORTABLES REVIEWED. BUYERS' GUIDE TO PORTABLE SETS.—(*Wireless World*, 5th June, 1929, V. 24.)

SUPER-REGENERATION WITH A PUSH-PULL OSCILLATOR.—L. D. Inskeep. (*QST*, May, 1929, V. 13, p. 45.)

The writer recommends the use of the push-pull oscillator described, as reducing the characteristic background roar.

MISE SOUS ÉCRAN DES BOBINES CYLINDRIQUES (Screening of Cylindrical Coils).—M. v. Ardenne. (Short summary in *L'Onde Élec.*, April, 1929, p. 31A, from *Funk.*, January, 1929.)

The construction of Faraday cages round the windings of a receiver is here considered. In practice, for broadcast wavelengths, a copper cage of diameter twice that of the coil might be used, a suitable thickness being 0.4—0.6 mm.

AERIALS AND AERIAL SYSTEMS.

ÜBER DIE RICHTCHARAKTERISTIK VON IN EINER EBENE ANGEORDNETEN STRAHLERN (On the Directional Characteristics of Radiators arranged in a Plane).—H. Stenzel. (*E.N.T.*, May, 1929, V. 6, pp. 165–181.)

Author's summary :—" The directional behaviour of periodically radiating systems is investigated. Such effects have long been known and investigated in optics under the title of diffraction. Recently they have played a rôle in acoustics (loud-speaker technique) and electricity (short waves). Special progress has also been made in submarine sound technique, for directive transmission (acoustic sounding) and reception (acoustic D.F.). Whereas in optics the chief considerations are the number and distance apart of principal maxima, here the chief rôle is played by the shape of the directional characteristic.

"It is shown in Section I that the directive sharpness, *i.e.*, the course of the main part of the characteristic, can be determined even for radiators distributed quite arbitrarily in the plane. For the determination of the complete characteristic, the arrangement of the radiators must be given in detail. Section II shows that for simple radiators of continuous form (straight line, circle, and circular plane) the characteristics can be determined very simply. Section III investigates the characteristics of individual radiators ('point-formed') distributed at regular intervals along a straight line or a circle, and optimum conditions for intervals and number of radiators are given. Finally, Section IV investigates the 'artificial' characteristic formed if the radiator system remains fixed but each radiator undergoes a corresponding varying phase-displacement. The optimum conditions, in this case, take another form. The important superiority of the circular-system over the straight-line system [in the matter of secondary maxima] is here brought out clearly."

The writer's investigation of the "artificial" characteristics of single circle-shaped systems shows that secondary maxima can only be kept small by arranging for a comparatively slight sharpness of directivity. For great sharpness, the secondary maximum will attain a value of 0.4. But he shows how this disadvantage can be removed by the use of two (or more) concentric circles, or (to a smaller extent) by a central radiator at the mid-point of the single circle. With inner and outer circles of diameter d_1 and d_2 given by $d_1/\lambda = 0.56$ and $d_2/\lambda = 1.28$, the space characteristic shows no sign of a secondary maximum, since this is less than one per cent. of the main maximum. The intensity of each concentric system is suitably proportioned; *e.g.*, for the single 8-radiator circle and extra mid-point radiator, the latter is given an amplitude eight times as great as that of each radiator in the circle.

NEUE RAHMENKONSTRUKTIONEN (New Designs of Frame Aerials).—M. v. Ardenne. (*Rad., B., F., f. Alle*, June, 1929, pp. 247–252.)

The sharpening of the directional properties of frame aerials, by a suppression of the open aerial effect, can be attained by the use of symmetrical arrangements, by compensation, or by screening. The present paper deals with the last method. The enclosing of the frame aerial by a metal tube (*e.g.*, as used by Telefunken—chiefly for protection against the weather) is impracticable for broadcasting purposes since for this wave-band the losses reduce the available voltage to a sixth of that given by an unscreened frame. The new construction gives large spacing between frame and screen, instead of the 0.5—1.0 cm. gap formerly used, and this gives excellent results, when combined with leads which are also screened, and with circuits which introduce no earth connection to the winding and also no connection to the screening. But even so, measurements showed that such screening by metal plate caused a considerable increase of damping, even when the plate was made of material of

low conductivity. A marked improvement, however, was found when the screen was made of a number of separate wires (30 to 100 per cent. of the number of turns in the actual winding). Like the metal plate screening, this screen of wires was interrupted at one point (centre of bottom section), each separate turn being broken at this point by an insulator. At a point opposite to this break, the screen wires were connected together by a cross wire which led to earth or to the receiver-screening. The possible use of the recently-introduced insulated and screened types of wire, for the simple construction of screened frames, is discussed: certain types would introduce too much self-capacity to be applicable to the broadcast waveband, but others would appear very suitable.

The paper then deals with the degree of directivity attainable with such screened frames, and the causes limiting this. Among these are the fluctuations in the direction of the incoming waves. All things considered, it should be possible to cut down the voltage produced by a local station—say 8 km. away—to about 1.5 per cent. of its maximum value. If the local station is very close, a frame which not only rotates but also tilts is of advantage. Such a mounting is also useful even at greater distances if the receiving apparatus as a whole possesses an open aerial effect, as it enables phase conditions to be obtained which can compensate for the effect and increase the sharpness of directivity.

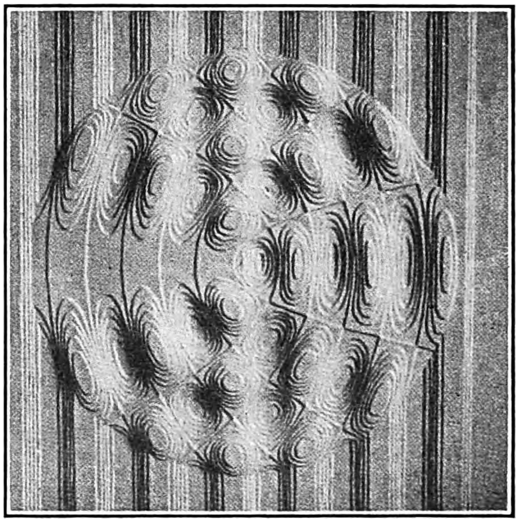
Beitrag zur Beschreibung des Interferenzgebietes in der Nähe von Empfangs-Antennen (A Contribution to the Characterisation of the Interference Zone in the Neighbourhood of a Receiving Aerial).—M. Dieckmann. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 161–166.)

An investigation of the field round a receiving aerial due to the combined effects of an in-coming wave-train and of the re-radiated waves from the receiving aerial. Since the electric field-vector, the magnetic field-vector, and the direction of propagation form a system of directions beyond the scope of the ordinary methods of representation, the writer uses photographs of plastic modelling to illustrate the effects described; hillocks representing electric field-strengths directed from beneath to above the plane of the paper, and hollows representing those in the reverse direction. Each relief model of one group of four represents the instantaneous state at different moments separated by intervals of one eighth of a period. These models therefore do not represent what would be found by electrical measuring instruments, since these record not the instantaneous but the integral values. Moreover, in these models it is assumed that the re-radiated circles of waves do not decrease in amplitude as they get further from the aerial; and—on the assumption that the aerial is tuned and without resistance—this constant amplitude is taken as equal to that of the in-coming waves.

On these assumptions, the formation of maxima and minima (large hillocks and large hollows) and of null values where the two sets of waves neutralise each other (flat surface) is shown. These null points form two separate groups of parabolas with a common focus at the foot of the aerial. One of these groups lies open to the direction of the transmitter, and its parabolas are changing their position and form from moment to moment, moving—increasing always in parameter—in the direction of propagation of the in-coming train. Each time that the innermost one reaches a parameter length equal to λ, a new parabola is formed on the joining-line between the stations. At this moment, the field along this line is uniformly null, as is seen by the flat surface of the model here reproduced where the distant transmitter lies to the left, and the receiving aerial can be seen as a raised point at the centre of the model.

The second group of parabolas remains constant in position and shape; their parameters are $\lambda/4$, $5\lambda/4$, $9\lambda/4$ . . . up to λ, and their intersections with the joining-line between the stations mark the nodes of the standing waves.

The next model represents the integral, instead of the instantaneous, values—as would be given by a measuring instrument. The next shows an



Model for the instant t/8 before the passage of a wave-crest.

instantaneous record similar to the first four but with the assumptions that the secondary waves vary in amplitude as the reciprocal of their distance from the aerial, and that the aerial has a radiation- but no internal resistance. Lastly, the decrease of the field distortion by the secondary waves, when the aerial is given an internal resistance as well, is shown by diagram.

It is to be noted that in all the above models the pure radiation field only has been considered, to the exclusion of the induction field; and the fact has also been neglected that the energy of the secondary rays is derived from the primary field.

VALVES AND THERMIONICS.

Measurements of the Grid-Anode Capacity of Screen-Grid Valves.—N. R. Bligh. (*E.W. & W.E.*, June 1929, V. 6, pp. 299–300.)

The valves tested were of the types S 625 and S 215. Measurements were made with filaments

cold. The average figure obtained for the first type was 0.022 and for the second type 0.014 $\mu\mu$F.

Determination of the Charge of Positive Thermions from Measurements of Shot Effect.—N. H. Williams and W. S. Huxford. (*Phys. Review*, May, 1929, V. 33, pp. 773–788.)

Authors' abstract :—Several new types of current fluctuations have been studied with special reference to the possible effects of both positive ions and electrons, and the influence of space charge. An emitter of positive potassium ions is described which has proved suitable for shot effect measurements. Results indicate that the discharge may be properly controlled and temperature limited currents obtained, giving a value for the $K+$ion equal in magnitude to the electron charge. Values resulting from an extensive series of electron charge determinations confirm the precision and expediency of several new methods which have been introduced into the experimental procedure. A detailed description is given of a simple and direct method of determining the shot circuit impedance.

Methoden zur Beseitigung des Mikrophoneffektes in Verstärkerröhren (Methods for the Elimination of the Microphone Effect in Amplifier Valves).—M. v. Ardenne. (*Zeitschr. f. tech. Phys.*, May, 1929, V. 10, pp. 185–187.)

" The avoidance of the disturbing noises which are caused by every external shock to modern amplifier valves with light, stretched filaments, has become a serious task " (reaction from the loud-speaker is here referred to, but work in the neighbourhood of motors—in aircraft—is mentioned later). The writer deals first with the damping of filament-vibration by mechanical design, or the arrangement—by the same means—that the natural period of vibration should be above or below the troublesome zone. Damping by electrical means is next treated ; unluckily the eddy-current effects produced by the current in the filament are too small. Reduction of the *effect* of filament-vibration, by increasing the distance between filament and the other electrodes, leads to a decrease of amplification ; such special valves should only be used in the first stage of a cascade. The rest of the paper deals not with the avoidance of vibration currents but with their neutralisation, according to the plans due to the writer and to Schlesinger. A constant magnetic field is produced either by a permanent magnet or by an electromagnet traversed by the filament current, and the vibrations of the filament produce in the latter L.F. induced currents which superpose themselves on the filament current, from which they can be separated by a small transformer. After one stage of amplification (if necessary) this L.F. is then adjusted in phase and used to oppose the direct disturbance due to the filament-vibration. One objection to this plan is the two-fold dependency of the neutralisation on the filament temperature, which changes (*a*) the filament period, thus upsetting the adjustment of the phase-regulating circuit, and (*b*) the amplification of the valves. This objection does not hold for those receivers which work under constant conditions of supply.

Recherches et Essais sur les Lampes de T.S.F. (Tests and Experiments on Wireless Valves). —A. Kiroloff. (*QST Franç.*, May and June, 1929, pp. 50–55 and 18–22.)

The May instalment of the series referred to in December, 1928 and July, 1929, Abstracts, deals with detector valves and various attempts to improve their working, such as the use of a " getter " (the question of the appearance of an " auto-current " is briefly discussed, together with Malarov's tests on the relation between the points at which this appears and the detector-action) and the use of special valves with multiple plates and grids to obtain double rectification, with increased efficiency. By a suitable modification of circuit, the ordinary two-grid valve can be used for this purpose ; the author's circuit for this is given, together with an apparently more satisfactory one using a pair of valves (but here the second valve appears to lack a filament). Improvement of detection by the aid of a heterodyne oscillator is illustrated by two circuits, and the special " organ of detection " due to Fromy is shown. The rest of the paper is devoted to various types of double-grid valve and their special circuits, including Blondel's design and the Frenotron where the inner grid is replaced by a small plate.

The June instalment deals with A.C.-heated valves (Bathenod's use of three-phase current is mentioned) and valves for short waves ; regarding the latter, the use of quartz for plate and grid supports is referred to, and also the advantage of symmetry and the need for a very good vacuum.

Dependence of Electron Emission from Metals upon Field Strengths and Temperatures.—R. A. Millikan and C. C. Lauritsen. (*Phys. Review*, April, 1929, V. 33, pp. 598–604.)

" This paper contains a full presentation of the reasons for believing, contrary to results recently obtained elsewhere (*cf.* de Bruyne, January Abstracts, p. 44) that field currents are only independent of temperature up to about 1100°K., and that at that temperature the energy of thermal agitation begins to assist the fields appreciably in causing the escape of electrons from metals. The precise form of function describing this dependence is not accurately determinable experimentally, but the form originally suggested by us fits the facts of observation thus far known satisfactorily ; not better, however, than does the theoretical form suggested by Houston."

Eine neue Lautsprecherröhre (A New Loud-Speaker Valve).—Telefunken Company. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, p. 183.)

Details and curve of the RE 114, with acid filament (3.8—4 v., 0.15 A.). Anode voltage 40–150 v. Slope 1.4 mA./v., $1/\mu =$ 20 per cent. ; internal resistance 3500 ohms, emission 40 mA. ; average anode current consumption 7 mA.

THE DEVELOPMENT OF THE OXIDE-COATED FILAMENT.—B. Hodgson, L. S. Harley and O. S. Pratt. (*Journ. I.E.E.*, June, 1929, V. 67, pp. 762–771.)

The full paper (with discussion) extracts of which were dealt with in April Abstracts, p. 212.

DIRECTIONAL WIRELESS.

DIE UNMITTELBARE MESSUNG VON ENTFERNUNGEN DURCH ELEKTRISCHE WELLEN (Direct Measurement of Distances by Electric Waves).—W. Burstyn. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 181–183.)

The method described is accurate only for distances up to a few kilometres, but that is enough for the primary object—the avoidance of collision or stranding for ships in fog. It depends on the fact that at short distances (*e.g.*, distances less than $\lambda/5$) radiation departs from the linear law. The paper begins by deriving, from the Hertz dipole equations, formulæ for the peak values of the electric and magnetic field strengths in dependence on wavelength and distance. These formulæ are, respectively :—

$$E = \frac{4\pi^2 Is}{\lambda^2}\cdot\frac{\sqrt{1-u^2+u^4}}{u^3} \text{ and } H = \frac{4\pi^2 Is}{\lambda^2}\cdot\frac{\sqrt{1+u^2}}{u^2},$$

where S is the length of the dipole and

$$u = \frac{2\pi}{\lambda} \times \text{distance.}$$

These formulæ can be applied unchanged to aerials with good earths, and their use (or the use of curves derived from them) enables the distance to be estimated or measured by the comparison of the strength of two waves of very different wavelength. One method of procedure is as follows :—The transmitter sends out, interlaced, the letter *a* on a 20 km. wave and the letter *n* on a 1 km. wave. To ensure that the two sets of signals should give the same heterodyne note, the short wave is controlled by the 20th harmonic of the long wave and "is modulated in time with this." The receiver, with a vertical aerial, is tuned to both waves : aural reception is by heterodyne, by a wave near 20 km., the long wave being heterodyned directly, the short wave after rectification ; the same valves are used for both, so that filament-fluctuations, etc., affect both waves equally.

The relations between transmitter and receiver are so chosen that at a distance of about 3 km. ($u = 1$ for the long wave) both waves are of equal strength. At greater distances the short wave signals are stronger, at smaller distances the long wave signals : the ratios being :—at 5 km., 0.8 ; at 3 km., 1.0 ; at 2.5 km., 1.25 ; at 2 km., 1.8 ; and at 1.5 km., 3.5. Thus as the distance decreases, the listener will hear first only the letter *n* ; then the gaps will be filled with a weaker note gradually strengthening, until at 3 km. an unbroken dash is heard ; after that, the warning signal *a* becomes more and more prominent. Estimates of the distance can be obtained by a calibrated shunt to weaken the long wave signals, adjusted so as to merge the two sets of signals into a long dash. These aural estimates are liable to an error, at 3 km., of 20% at most. A direct-reading method, independent of the ear, is also possible ; in this case long dashes or continuous transmission on both waves is employed, and a crossed-coil indicating instrument at the receiving end.

If the magnetic component is made use of instead of the electric, by the employment of a frame aerial, the increase of the *a* signal over the *n* signal takes place over a longer distance-change. Another method still is to compare the electric and magnetic components of a single (long-wave) transmission ; or to measure the phase-displacement of the two components $\left(\tan\phi = \frac{1}{u^3}\right)$, a frame and a vertical aerial being used in combination. But the first method is the simplest and most reliable, and any discrepancy due to the differing attenuation of the long and the short waves is negligible over the short distances in question, particularly over sea.

NOUVELLES CARTES AÉRIENNES POUR L'EMPLOI DE LA T.S.F. EN NAVIGATION (New Aerial Charts for the Use of Wireless in Navigation).—L. Kahn. (*L'Onde Élec.*, March, 1929, V. 8, pp. 87–102.)

The writer's new type of chart is particularly designed for use in aircraft, for quick and direct reading of the great circle course. Calculations by spherical geometry are entirely inadmissible, and the various attempts at simplification by gnomonic projection (Hilleret, Germain, and Gernez charts—*cf.* Abstracts, 1928, V. 5, p. 402) have certain defects. The Favé chart, in which the great circles are projected on to a Mercator planisphere, is probably better, but for use in the aeroplane itself even this is too cumbersome and complex. The new plan is to have separate charts for each route. Each chart is derived from a band of the earth's surface whose centre line is the great circle between the two places, the band being opened out flat and the chart deformed as is done in a planisphere map : thus the great circle itself is neither stretched nor twisted, and the angles are preserved. Each chart, in fact, resembles in its properties a band of a planisphere close to the equator. A section of the paper shows how the scheme can be utilised for astronomical bearings at sea.

ÉTUDES DES RADIOPHARES POUR AÉRONEFS PAR LE "BUREAU DES STANDARDS" (The Bureau of Standards Development of Radio Beacons for Aircraft). (*L'Onde Élec.*, April, 1929, V. 8, pp. 143–159.)

A survey, up to November, 1928, of the work on "equi-signal radio beacons" to which several references have been made in these Abstracts. The present paper includes diagrams of connection of the transmitting and receiving systems.

FIELD INTENSITY CHARACTERISTICS OF DOUBLE MODULATION TYPE OF DIRECTIVE RADIO BEACON.—H. Pratt. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 873–878.)

An investigation of the field intensity characteristic patterns under varying conditions, when both carrier waves are modulated (for the visual

2-reed indicator—Abstracts, 1928, V. 5, p. 582). The condition where the two carrier voltages supplied to the aerial system have the same amplitude and are in phase is found to be the most favourable, leading to two courses only.

DIRECT-READING DIRECTION FINDER. (German Patent 471633, Rempe, pub. 14th February, 1929.)

Waves received on a directional aerial are rectified and used as the exciting current of a small dynamo, whose output voltage is indicated by a suitable instrument and serves as a measure of the direction of the in-coming waves.

PORTABLE DIRECTION FINDER: WIDE RANGE COMBINED WITH SENSITIVITY AND ACCURACY. —R. L. Smith-Rose and E. L. Hatcher. (*Wireless World*, 12th June, 1929, V. 24, pp. 614–616.)

A seven-valve supersonic heterodyne receiver is employed, and the working wavelength range extends from 40 to 3,000 metres. Transportability is improved compared with earlier models.

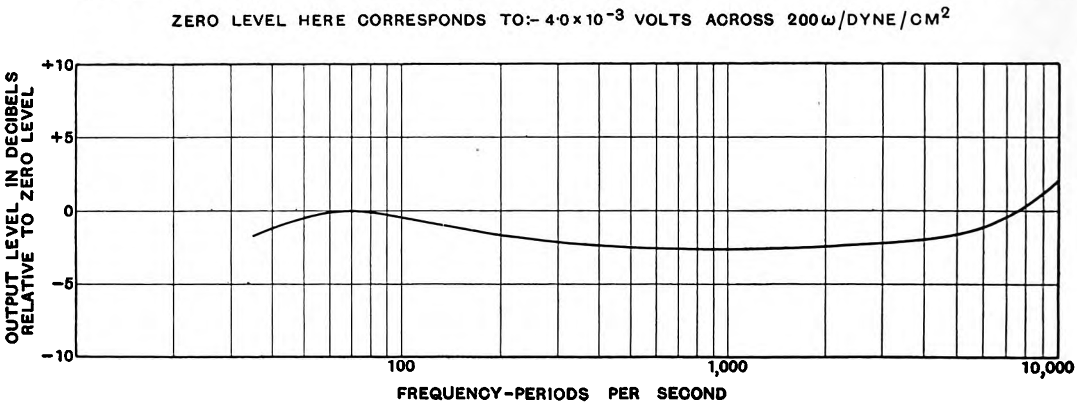
COMPULSORY D.F. ON SHIPS. (*Wireless World*, 12th June, 1929, V. 24, p. 623.)

Eighteen nations have signed the new convention for the safety of life at sea, among the provisions of which is a clause making compulsory the fitting of D.F. apparatus on all passenger ships of 5,000 tons gross and upwards.

ACOUSTICS AND AUDIO-FREQUENCIES.

A SOLUTION OF THE PROBLEM OF THE BROADCASTING MICROPHONE.—A. H. Reeves. (*Elec. Communication*, April, 1929, V. 7, pp. 258–265.)

In their search for the perfect microphone the International Standard Electrical Corporation has reverted to the "MS.1670" condenser-microphone (Wente) but with a new circuit which greatly reduces background noise (an improvement of 14–24 decibels in speech/noise ratio); the essential principle being the utilisation of the capacity changes to alter the tuning of an inductance-capacity circuit coupled weakly to a R.F. oscillator circuit just out of tune with it. The resulting modulated carrier wave is then rectified. Among the several advantages of this method, over the earlier plan of direct amplification of the L.F. fluctuations due to the microphone, perhaps one of the greatest is the elimination of high (15 megohms) resistances with their resulting "thermal agitation" noises (Abstracts, 1928, V. 5, p. 581) and noises due to irregular leakage. As regards output volume, the new combination, with an average speaker 5 feet from the microphone, gives an output level of minus 20 decibels. (As zero level corresponds to 5.9 mw., this corresponds to a maximum instantaneous peak power of 0.059 mw.). The frequency characteristic reproduced below shows that up to 8,000 cycles the characteristic lies within $\pm 1\frac{1}{2}$ decibels, and above that there is a small rise "which is an asset rather than otherwise, owing to the deficiencies of receiving apparatus." No background noise can be detected under conditions of normal operation in the studio, and no overloading could be detected under conditions which caused blasting with a high quality diaphragmless carbon microphone.



Overall characteristic of equipment.

VOLTAGE SURGES IN AUDIO-FREQUENCY APPARATUS. —E. M. Fisher. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 841–848.)

Transient voltages of over 2,000 are shown to occur across the secondary when the normal plate current of a high inductance audio-frequency transformer is opened. A type 201 A valve, without departing from recommended values of grid and plate voltages, gave secondary surges approaching 2,500 v.—which would jump a gap of 3/16 inch. The use of the larger valves now quite common makes possible even higher transients in coupling and output transformers (*cf.* Sims on the Pentode, March Abstracts, p. 152). Except perhaps in testing, the ordinary radio set does not as a rule have the plate circuit opened: but pulling a valve out of its socket with the filament "on," or plugging loud-speakers in, might easily cause transients of the magnitudes observed—as might

also a small surge as the "B" eliminator voltage builds up. Under such a stress, some transformers flash across internally—thus giving an indication of why transformers sometimes "go noisy." A small safety-gap is suggested as a protection. The paper is illustrated by a number of oscillograms showing that these transients are oscillations of definite frequency and magnitude, depending on the primary current, inductance, and secondary distributed capacity. The manner of breaking the circuit has a minor influence.

The oscillograms were taken by an "inverted valve" arrangement, which forms with an oscillograph a means of recording which is rapid and at the same time uses practically no energy. The functions of grid and plate are reversed, the grid being made positive so that it draws a current large enough to work an oscillograph. Any negative voltage applied to the plate then has an effect on the grid current equivalent to reducing the grid voltage by $1/\mu$ times as much as that of the plate. As the transients are oscillatory, a negative plate bias is applied to keep the plate from going positive when the oscillation is reversed.

A New Moving Coil Loud Speaker.—(*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 197–198.)

In the conventional m.c. loud-speaker "the cone itself is suspended by means of a small flexible paper web at the apex and an annular strip of material at the edge. It is in the latter that the chief defect . . . originates . . . If the material of the ring is loose, the cone movement will not be axial. It is well known that the currents in the coil cause forces which tend to tilt the coil as well as propelling it axially, and if this can occur the coil will touch the faces of the magnet poles. Hence arises a necessity for a wider air-gap in the magnetic system, which in turn means a heavier magnet and field winding, with increased energy consumption. If, on the other hand, the supporting material is stretched to avoid sagging, the natural period of vibration of the cone as a whole is raised into the range of audible frequencies, and the result is generally a marked resonance at some point between 40 and 80 cycles with a sharp cut-off below. . . ."

The article then describes and illustrates the Marconiphone m.c. loud-speaker, due to Round, in which the cone is supported by two paper webs on a stout brass spindle which screws into the centre pole of the magnet. "At the edge there is merely a thin strip of soft felt, which does not support or restrain the cone in any manner. The weight is taken by the larger paper spider, which cannot sag, yet permits of absolutely free axial motion."

The Vogt Electrostatic Loud Speaker.—(*Wireless World*, 29th May, 1929, V. 24, pp. 553–556.)

An illustrated article from a Berlin correspondent giving technical details of a new and improved type with differential movement. Polarising voltage is from 500–700 v. To avoid danger, the loud-speaker, receiver, amplifier and battery eliminator are all built into one case. The writer suggests a method of connection (in which the polarising voltage is applied to the central membrane, the front plate being at earth potential and the back plate carrying the signal voltage) which he says would decrease very considerably the danger of receiving serious shocks from the plates of the loud-speaker.

Design Data for the Moving Coil: Some Notes on the Most Efficient Coil and its Correct Design.—L. E. T. Branch. (*Wireless World*, 29th May, 1929, V. 24, pp. 561–564.)

An All-Electric Amplifier: High Quality Reproduction of Gramophone Records. Part I.—A. P. Castellain. (*Wireless World*, 19th June, 1929, V. 24, pp. 634–637.)

The Transmission of Sound through Partitions. II.—Vibrating Partitions.—A. H. Davis and T. S. Littler. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 1050–1062.)

Geschwindigkeitsmessungen mit erhitzten Drähten in stehenden Luftwellen (Velocity Measurements with Heated Wires in Stationary Air Waves).—G. Goldbaum and E. Waetzmann. (*Zeitschr. f. Phys.*, 4th April, 1929, V. 54, No. 3/4, pp. 179–189.)

The periodic and the constant cooling effects produced on heated wires by the velocity-amplitudes in a sound field were measured relatively along stationary air-waves of various periods. Tests between 100 and 1000 cycles per sec. lead the authors to doubt whether the constant cooling effect can give absolute measurements of sound intensity, the curves showing (for constant velocity-amplitudes) a decrease of (constant) cooling-effect which *increases* with increasing frequency.

PHOTOTELEGRAPHY AND TELEVISION.

Der Fernseher Telefunken-Karolus (The Telefunken-Karolus Television Apparatus).—(*E.T.Z.*, 23rd May, 1929, V. 50, p. 761.)

Report of a recent demonstration, with photographs of the transmitting and receiving cabinets. The reproduction is on a screen 30 × 30 cm., but for smaller types of receiver this would be reduced to 10 or 15 cm. length of sides. The number of elements is 2,500, but "this could easily be increased." The report speaks of the results as comparable in quality with the early cinematograph pictures. It is not definitely stated whether transmission was by wireless. Karolus said that difficulties in transmission could be overcome by the use of a 50 m. wave, though at first only for a broadcast range of at most 50 km.

La Télévision ou Transmission à Distance des Images Animées (Television, or Transmission to a Distance of Animated Pictures).—— Belus. (*La Tech. Moderne*, 1st March, 1929, V. 21, pp. 129–133.)

Facsimile Picture Transmission: Discussion.—V. Zworykin and others. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 895–898.)

Discussion on the paper referred to in June Abstracts, p. 334. Among the various points arising

are the following :—the author says that he has thoroughly tried introducing the A.C. component by supplying A.C. to the photoelectric cell, instead of by the present method of interrupting the light: the trouble is that with the high frequency necessary (at least 3000 cycles) the capacity leakage of the cell is relatively large. Ballentine says that the G.E.C. finds the major problem to be the "getting across and through the ether" of short-wave high-speed signals. The author describes his synchronising arrangement; the tuning fork is driven by a valve and a resistance is included in the grid circuit of this. Every time the correcting impulse comes to the terminals of the resistance it changes slightly the oscillation of the valve, and this corrects the fork. This is sufficient to correct the fork if the frequency difference between the two forks does not exceed about 1 beat in 20 seconds. One lumen gives about 20 micro-amperes through 0.5 megohm, with a cæsium cell; the latter was found to be about 100 times as sensitive as a potassium cell. 64 lines per inch are used; the author agrees that for fine detail the G.E.C. practice of 100 is better; he has seen systems in Europe using 130, but considers that anything above 100 is waste of time and of band-width. Ranger however points out that with 120 lines to the inch a whole line can be missed through fading, etc., without preventing the reception of a perfectly legible type-written copy. He has certain criticisms to make of the author's pick-up system, and then advocates relieving the "poor link through space" of the extra duty of synchronisation; pointing out that the Radio Corporation maintains separate tuning forks on opposite sides of the Continent, within 2 parts in a million, and the drift in the picture is not noticeable.

DER BILDTELEGRAPH SYSTEM SIEMENS-KAROLUS-TELEFUNKEN (The S.K.T. Picture Telegraphy System).—P. Arendt. (*E.T.Z.*, 23rd May, 1929, V. 50, pp. 744–748.)

A description illustrated by photographs of the latest results, of the components used in the apparatus, and of the complete apparatus.

A NEW SFÉROGRAPH TRANSMITTER.—L. Chauveau. (*Rev. Gén. de l'Élec.*, 4th May, 1929, V. 25, pp. 674–675.)

This differs from the transmitter previously described (Abstracts, 1928, V. 5, p. 649): a photoelectric cell is inside the drum, and is illuminated by a small source of light, outside the drum, travelling parallel to the axis of the latter.

DER GEGENWÄRTIGE STAND DER BILDTELEGRAPHIE. V.—DAS HOCHWERTIGE BÉLIN-VERFAHREN (The Present State of Picture Telegraphy. V.—The Improved Bélin System).—F. Noack (*Rad., B., F., f. Alle*, June, 1929, pp. 261–264.)

Continuation of the series dealt with in May and June Abstracts.

Where it is necessary to compete in speed with other systems, the new Bélin apparatus has abandoned the potassium bichromate relief method of transmission and uses—like the Lorenz-Korn system—an optical method which is here described and illustrated, together with the receiving apparatus. The most interesting point about the latter is perhaps the use of an "absorption prism" which, working in conjunction with a mirror-galvanometer, controls the light reaching the photographic paper.

LA PHOTOTÉLÉGRAPHIE D'AMATEUR (Amateur Phototelegraphy).—R. Mesny. (*Bull. d. l. Soc. franç. d. Élec.*, May, 1929, V. 9, pp. 511–524.)

PHOTOELECTRIC CELLS.—(German Patent 472485, Siemens-Shuckert, published 28th February, 1929.)

Cells independent of temperature are made by mixing the photoelectrically active material with material of higher melting point such as barium.

PHOTOELECTRIC CELLS AND METHODS OF COUPLING TO VACUUM TUBES.—T. P. Dewhirst. (*QST*, June, 1929, V. 13, pp. 17–20.)

Among the circuits given are :—a good circuit for general television work; circuits (which can be used for working relays) enabling the same battery to be used to supply voltage to the triode anode and to the photoelectric cell; a circuit (where a linear frequency response is not essential) giving an enormous gain by the use of a screen-grid valve.

LIGHT CONTROL FOR PICTURE TELEGRAPHY, ETC.—(German Patents 471160, Telefunken, published 8th February, 1929; 471720, Karolus, published 18th February, 1929.)

(1) In the control of polarised light by an anisotropic substance, the resultant effect depends not only on double refraction but also on rotation of polarisation: the latter prevents the obtaining of complete darkness by the use of crossed Nichols. This difficulty is overcome by the use of a second anisotropic substance; *e.g.*, a right-handed quartz succeeding a left-handed quartz; only the latter being excited electrically. (2) This is the Karolus 1924 patent on the use of the Kerr cell.

KNIFFE BEIM BILDFUNKEMPFANG ("Tips" for Wireless Picture Reception).—*Rad., B., F., f. Alle*, June, 1929, pp. 252–254.)

A table is given showing 15 common symptoms of trouble, their causes and their remedies.

MEASUREMENTS AND STANDARDS.

SUR UN NOUVEL EMPLOI DES QUARTZ PIÉZO-ÉLECTRIQUES (A New Use for Piezoelectric Quartz).—G. Siadbei. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1390–1391.)

A method of using piezoelectric control for chronometry is suggested which should lead to an accuracy of time-keeping "unknown by any other method." Two pieces of quartz cut from the same plate are stuck together and trimmed in one piece so that their dimensions are exactly the same: on separation, one piece is lightly polished so that its thickness is diminished to such an extent that the difference in frequency of the two pieces produces

a beat with a period about 1 second. Plates about 1 mm. thick, with a frequency round 3 million, have the advantage of using very small amounts of electrical energy with a correspondingly smaller tendency to heating up. The two oscillators formed from these plates are kept at a suitable distance, and by means of coupling coils apply their variations of potential to the two grids of a tetrode: the plate current of this is therefore modulated by the beat frequency, and can be used in various ways to control a chronometer or—for phototelegraphy, etc. —a phonic motor (in the latter case a more suitable beat frequency would be chosen).

The only disturbing factor is the effect of temperature-change. A change of 1 degree causes, according to Meissner, a change of 0.6 in a million; to Powers, 5; and to Cady, about 20. Such changes would produce a 24 hour error of 0.0516, 0.432 and 1.728 second respectively. A thermostat control which would keep the temperature constant within 1/100 or even 1/1000 of a degree, and a rigorous selection of quartz with small temperature coefficient, would enable a remarkable constancy of time-keeping to be obtained. Without the complication of thermostatic control, merely by the fairly rough registration of the temperature changes, corrections can easily be made since the frequency variation is strictly a linear function of the temperature.

Étude préliminaire d'un Diapason de Quartz dans un Vide Élevé (Preliminary Study of a Quartz Tuning-Fork in a High Vacuum).—Holweck and Lejay. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1541–1543.)

This apparatus is similar in principle to that used by Wertenstein (*Phil. Mag.*, July, 1928) in his viscosity manometer. An elastic system, oscillating at right angles to its own plane, is formed by a sharp *V* of two quartz threads, 0.2 mm. in diameter and 15 cms. long. The two extremities of the *V* are fused to a solid quartz fork with a thick stem which supports the whole system. The angle of the *V* carried a small quartz ball, and the whole "may be prolonged by a thread, providing easy observation and an adjustment of period by gradual shortening." The whole, which behaves like a flexible blade fixed at one extremity, is enclosed in an air-tight container of glass or quartz, the thick stem of the quartz fork being pinched or fused to the interior of the envelope. With this envelope highly exhausted, if a shock is given to the whole system the time taken for the amplitude of the vibrations to die down to one half is several hours (provided that the whole apparatus is fixed very rigidly to a very solid mount, so that the losses in the support are reduced as much as possible. These are the only losses to be considered, those due to the elastic viscosity of the quartz and to friction with the gas being negligible).

The frequency is considered likely to be remarkably constant, reasons for this being given and preliminary experimental verification quoted. More accurate measurements than those given (which showed an accuracy of about 1 ten-thousandth of a second in two seconds) must await the making of a second similar apparatus. Various applications are outlined. It is suggested that the vibrations could be maintained by an arrangement using the pressure of light.

Measurement of the Frequencies of Distant Radio Transmitting Stations.—G. Pession and T. Gorio. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 734–744.)

English version of the Italian paper referred to in Abstracts, 1928, V. 5, p. 643. Regarding the tuning fork controlling the multivibrator, the writers say: ". . . we reached the conclusion that in measurements requiring a high degree of precision (1 to 5 parts in 100,000) it is necessary to calibrate the tuning fork each time before the measurement and to maintain an absolute constancy of temperature." The method adopted is to combine the fork current with that of a small Siemens 100-toothed induction alternator and to record, through a chronograph, the beats thus formed, the number of revolutions, and the frequency of the alternator together with the time furnished by a pendulum of the Astronomical Observatory. A stroboscopic arrangement is used for the rough adjustment of alternator speed, which need not be kept absolutely constant.

A Direct Reading Frequency Bridge for the Audio Range, based on Hay's Bridge Circuit.—C. I. Soucy and B. de F. Bayly. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 834–840.)

"The bridge is portable, simple to construct, and makes use of external connection—for the variable resistances—to two standard decade non-inductive resistance boxes. Its operation is convenient and permits of a precision of balance of 0.1% with a probable error of less than about 0.25%."

The range is about 50–5,000 cycles. The method depends on the fact that in the Hay bridge for inductance measurement, the equation for the inductance is nearly independent of frequency, but the equation for the resistance of the inductive coil is dependent on frequency and a variable resistance; therefore by introducing a variable resistance in series with the inductance, an arrangement is obtained in which the frequency is determined directly in terms of this variable resistance. A very similar bridge was described by Kurokawa and Hoashi in *J.I.E.E., Japan*, No. 437, pp. 1132–1138.

Constancy of Oscillator Frequency. (*Elec. Times*, 6th June, 1929, pp. 921–922.)

After a short description of various valve generator circuits, including the Hartley and Colpitt's circuits, and a reference to electro-mechanical methods of keeping the frequency constant, the paper devotes itself to purely electrical methods of frequency stabilisation, dealing first with Horton's arrangement used on the Trans-atlantic telephone service (*Bell Tech. Journ.*, July, 1924); then with the B.B.C. "Master Oscillator" (Eckersley, *Journ. I.E.E.*, May, 1928) as used at 5GB; Fromy's oscillator (*L'Onde Élec.*, Sept., 1925) based on the idea of avoiding phase differences by segregating the tuned circuit from both grid and anode; and lastly Colebrook's Modulating Wavemeter circuit (*E.W. & W.E.*,

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Dec., 1927). The following claims for the various methods are quoted:—Horton: H.T. Voltage change from 100 to 150 v. causes 0.04% frequency change; filament current change from 1.1 to 1.4 A. causes 0.03% frequency change; changes in frequency from changes of load impedance are negligible. B.B.C. "Master Oscillator," no results given. Fromy: on 300 kc., a variation of 1 in 100,000 as filament voltage is varied between 4.75 and 6 v., while the variation is much less than this over a region 5 to 5.5 v. Changes of anode voltage give rise to frequency variations of the same order of magnitude. "Without any very special care the attainment of at least 1 in 50,000 is very easy, but the disadvantage of four coils and three condensers" (which may be "ganged" if they and the coils are suitably chosen) "is considerable both from the obvious point of view of economy and also from the difficulty of obtaining well-matched components to ensure the maximum frequency stability." Colebrook: a frequency stability of better than 1 in 1,000 is claimed for filament variations of 1.5 to 2 v. and H.T. variations of 30–70 v. The modulating property is of great advantage in working with a non-oscillating receiver, and in helping to "grope" for tune even if it is cut off later to permit the final working to be done with heterodyne. The four circuits are shown in the diagrams given below.

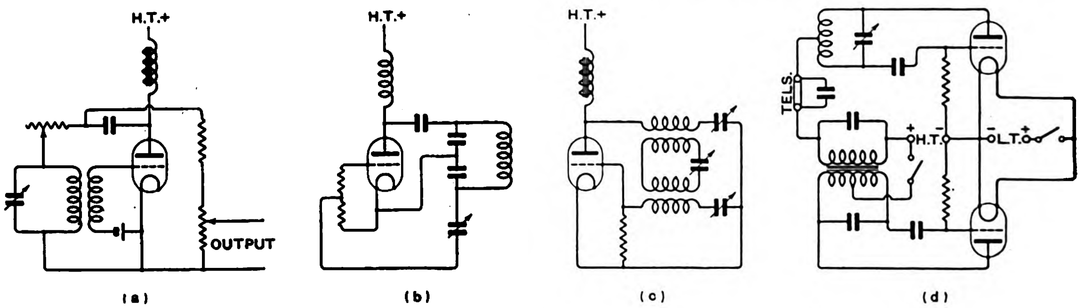
(which may contain helium) connected in series with the crystal. Sensitivity can be increased by an auxiliary voltage permanently across the electrodes of the glow-tube.

Piezoelectric Control of Low Frequency Oscillations. (German Patent 47163c, Radio Corp. New York, pub. 15th February, 1929.)

For slow oscillations the crystal is allowed to vibrate like a prong of a tuning fork: three electrodes are used, a pair (of the same polarity) one on each side of the fixed end, and the third (of opposite polarity) opposite this fixed end, so that the lines of force run from the sides to the end.

Piezoelectric Patents.—(American, 1696626, Crossly; 1692074, Burtes; 1688713, Hund. German, 469208, Radiofrequenz.)

(1) For the prevention of frequency variation and of too much load on the crystal, a grid bias is provided; two ways of doing this are shown. (2) Damaging sparking between crystal and electrodes is prevented by interposing a separating layer, non-hygroscopic, free from organic particles and highly insulating, such as water-glass. (3) A coupling is formed through the crystal between grid and anode circuits, one crystal electrode going to the grid and the other to a metal ring which



(a) *Horton's Oscillator*; (b) *B.B.C. Master Oscillator*; (c) *Fromy's Oscillator*; (d) *Colebrook's Modulating Wavemeter.*

Multivibrator Circuit using Four-electrode Valve. (German Patent 472128, Philips' Co., published 23rd February, 1929.)

The number of valves used in a multivibrator circuit can be halved by using two-grid valves instead of triodes. A periodically discharging condenser (2,000 cm. to 1 microfarad) is connected across the two grids, one of which goes—through a resistance of about one megohm—to the cathode, the other—through a resistance of a few thousand ohms—to a point in the anode circuit.

Piezoelectric Glow Resonance Indicator. (German Patent 471631, Telefunken, pub. 18th February, 1929.)

The ordinary piezoelectric glow resonators give very faint glow and moreover their wavelength can only be changed after removing the crystal from its exhausted container. According to this invention, the glow is provided by a special glow-tube

encircles, without touching, part of a helix in the anode circuit. (4) The audio-frequency currents which accompany the luminous charges on a piezoelectric crystal in a more or less evacuated container, when the crystal is excited by a H.F. alternating field, are used as an indication of resonance between the field and the natural frequency of the crystal.

Internationale Vergleichungen von Frequenznormalen für elektrische Schwingungen (International Comparisons of Frequency Standards for Electrical Oscillations).—E. Giebe and A. Scheibe. (*Zeitschr. f. Hochf. Tech.*, May, 1929, V. 33, pp. 176–180.)

An analysis of the 1926–27 international comparison of frequencies, together with some later results (1927–28) with some Bureau of Standards quartz resonators with thermostatic control and with some German piezoelectric "glow" resonators

(in a mixture of neon and helium at a few mm. pressure). These latter have a much smaller temperature coefficient than the quartz oscillators and can therefore be used without thermostatic control. They seem to give about as good a constancy as the temperature-controlled oscillators, their average deviation being of the order of $\pm 0.4 \times 10^{-4}$ cycles per sec.

PIEZOELECTRIC WAVE CONTROL. (French Patent 648687, Soc. le Matr. Anon., pub. 12th December, 1928.)

Instead of using several crystals in series (to avoid overloading), several pairs of electrodes are used at different points of the same crystal: these pairs are connected in series, alternating from one side of the crystal to the other.

DIE ABHÄNGIGKEIT DER PIEZOELEKTRISCHEN KONSTANTE BEI QUARTZ VON DER TEMPERATUR (The Temperature-variation of the Piezoelectric Constant of Quartz).—A. Andreeff, V. Fréederiksz and I. Kazarnowsky. (*Zeitschr. f. Phys.*, 27th April, 1929, V. 54, No. 7/8, pp. 477–483.)

The investigation was by the method of electrical oscillations and extended to the range 15 to 500° C. It was found that the piezoelectric modulus decreased very little with rising temperature (a maximum of 12% in the whole range named). The authors are not yet convinced that even this change is a true temperature variation of the modulus. The results contradict those of other workers who employed only electrostatic methods. It is mentioned that above 500° C. no resonance curve could be plotted, but oscillations could be detected up to 575°. Above this point all attempts to set the quartz in oscillation failed.

A PORTABLE RADIO INTENSITY-MEASURING APPARATUS FOR HIGH FREQUENCIES.—J. Hollingworth and R. Naismith. (*E.W. & W.E.*, June, 1929, V. 6, pp. 316–318.)

Abstract of the I.E.E. paper. The instrument described is capable of measuring field intensities of 10 to 10,000 microvolts/metre in a waverange 25–66 metres. It can be carried in a light car, its weight (without batteries) being about 60 lbs. The receiver includes a detector valve and a retroactive tuning control valve, with one stage of L.F. amplification and an extra stage (L.F. rectifier) for galvanometer working. A separate heterodyne is used to obtain the audio-frequency. An open aerial is used, connected to earth through a high resistance; its height is kept well below a quarter wavelength. Local injection of signals is obtained by an attenuator, a resistance potential divider being adopted after a condenser potential divider had proved unsatisfactory.

RADIO RECEIVER TESTING EQUIPMENT.—K. W. Jarvis. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 664–710.)

A long article on methods and apparatus of the Crosley Radio Corporation. Among the apparatus may be mentioned a "distortometer" enabling the distortion and overload of the output to be directly measured.

THE PROBLEM OF "TURN-OVER" AS APPLIED TO VALVE-VOLTMETERS.—M. Reed. (*See under* "Properties of Circuits.")

VACUUM-TUBE VOLTMETER DESIGN.—H. R. Lubcke. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 864–872.)

Author's summary:—It is shown that for every input range and meter a set of optimum conditions exist, which insure maximum readability, economy, and minimum operating current. Equations are developed (and illustrated with several examples) for the rapid design of a meter for a predetermined range. Optimum conditions are imposed. The dependence of the range secured upon plate circuit impedance is shown and its variation with frequency explained. The procedure for eliminating frequency error up to and including radio frequencies is illustrated.

THE USE OF THE ELECTRON TUBE PEAK VOLTMETER FOR THE MEASUREMENT OF MODULATION.—C. B. Jolliffe. (*Proc. Inst. Rad. Eng.*, April, 1929, V. 17, pp. 660–663.)

Nelson and Conrad have each patented methods of measuring the degree of modulation, but both systems have the disadvantage of measuring the amplitude of the audio-frequency current before it is impressed on the R.F. current. An oscillograph is the ideal means but is expensive and not readily portable. The thermionic peak voltmeter described by van der Bijl may conveniently be used to measure the modulation of a R.F. current whose maximum value for complete modulation varies between the limits zero and twice the maximum unmodulated R.F. current. If the peak value of the R.F. current is measured without modulation, and then the modulation is applied and the peak value again measured, then the percentage modulation $= \dfrac{(I_{\text{mod.}} - I_r) \times 100}{I_r}$. Accuracy by this method appears to be to within about 4%.

DIE BESTIMMUNG DER BRAUCHBARKEIT VON SPULEN (The Determination of the Serviceability of Coils).—H. Kottas. (*Rad. f. Alle*, May, 1929, pp. 201–208.)

A method is described of comparing the merits of different coils, for various wavelengths. The coil is connected between grid and anode of a Hartley circuit, and a tapping lead from the earthed end of the filament is connected to each turn, one after the other: for each position, the circuit condenser is adjusted to the point where oscillations just break off. A curve is thus plotted, and from the area of this curve the "serviceability" of the coil for that particular wavelength is deduced.

SUBSIDIARY APPARATUS AND MATERIALS.

AUTOMATIC BATTERY CHARGING.—O. Gramisch. (*Elektrot. u. Masch:bau*, 10th March, 1929, V. 47, pp. 201–202.)

An automatic make-and-break depending on voltage is unsatisfactory for the purpose, since the voltage curve towards the end of the charge is practically horizontal. In the course of the article

the writer recommends the "Pöhler interrupter," a combination of a relay dependent on voltage and a timing-mechanism; the relay comes into action at the voltage where intense formation of gas takes place—a point where the voltage rises very rapidly.

A Barretter with Long Life.—(French Patent 653087, Thomson-Houston Co., published 16th March, 1929.)

Iron wire ballast resistances, even when enclosed in hydrogen at low pressure, have lives of only about 1000 hours owing to evaporation of the iron. The present invention uses a nickel wire in series with an iron wire, in an atmosphere of hydrogen or helium at from 1–10 mm. pressure. The ballast-action of the nickel wire begins at a temperature 100° C. lower than that at which the iron wire ballast-action begins, and ends just where this begins. The life is said to be 40–50 times as great as that of an iron resistance in hydrogen.

Zernike Thermopile.—(*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 202–203.)

A new thermopile of 8 elements of improved Bismuth alloys giving an E.M.F. of 120 microvolts per degree Celsius. The usual disadvantages of such elements, high resistance and slow response, are compensated here by making the wires extremely short. The instrument is so shielded that it possesses great insensitivity to outside disturbances. Resistance is 20 ohms, and the position of equilibrium is attained within 3 seconds after radiation falls on the pile.

The Use of Wollaston Strip for Suspensions.—D. W. Dye. (*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 203–204.)

Cathode-ray Oscillograph with Rapid Automatic Starter.—W. Krug. (*E.T.Z.*, 9th May, 1929, V. 50, pp. 681–685.)

In an article on the recording of surges, the writer mentions the successful development of a pre-deflecting arrangement (*cf.* Berger, Abstracts, 1928, V. 5, p. 525) which allows the oscillograph to be set working automatically with a lag of only 10^{-9} to 10^{-8} sec. The method allows the ray pre-deflection and the time-axis pre-deflection to be accomplished with one pair only of time-axis plates. Details are promised in a later paper.

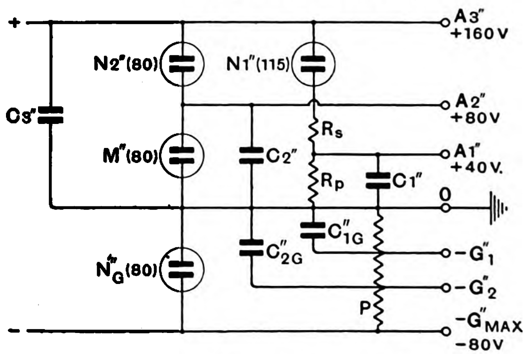
Lightning Surges on Medium Voltage Power Networks, recorded by Cathode-ray Oscillograph.—K. Berger. (*Bull. de l'Assoc. Suisse des Élec.*, 7th June, 1929, V. 20, pp. 321–338.)

Logarithmic Scale for Beat-Frequency Oscillator.—E. R. Meissner. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 879–881.)

The equation is developed governing the shape of plates for a condenser which, when used in a beat-frequency oscillator, would give a logarithmic frequency scale—so that it would be possible to set (say) a 90 cycle frequency to the same number of significant figures as 900 or 9000.

Glimmstrecken-Spannungsteiler für Netzanschluss der Anoden- und Gitterspannungen (Glow-discharge-gap Voltage-dividers for Mains Supply of Anode and Grid Voltages).—L. Körös. (*E.T.Z.*, 30th May, 1929, V. 50, pp. 786–788.)

The employment of ohmic resistances, as voltage-dividers and series resistances in mains eliminators for anode and grid supply, leads to voltage fluctua-



tions, oscillation and distortion, owing to the effect of change of load. Schröter has patented a method of avoiding such voltage fluctuations by the use of a glow-discharge tube in a parallel connection, but the writer points out objections to this plan (*e.g.*, the impossibility of making the grid voltages independent of the fluctuations) and advocates instead the substitution of similar tubes for the usual ohmic resistances.

The diagram reproduced above shows such an arrangement to provide three constant anode voltages and tappings for constant grid biases. The figures in brackets against the glow-discharge tubes represent their working voltages. The tubes N_2'', M'' and N_G'' are always sufficiently loaded to prevent oscillation through the condensers. To prevent oscillations from the tube N_1'', which has to supply the anode circuit of the audion valve taking a comparatively small current, the resistance R_s is introduced, of value 2500–3000 ohms. The tubes incidentally act as indicators, taking the place of milliammeters, since any fluctuations of brightness can be observed.

Cold Cathode Rectification.—A. E. Shaw. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 849–863.)

Author's summary:—Asymmetric conductivity in a gas between two electrodes can be accomplished without the use of a hot cathode, if the relative areas of the electrodes are widely different. This paper presents the results of an investigation of the discharge phenomena and asymmetric conductivity in a cold cathode rectifier tube containing two anodes and one cathode, when utilising: (1) one anode and one cathode; (2) two anodes and one cathode; and (3) two anodes and one cathode and a low-pass filter circuit. The electrodes are situated in a gaseous atmosphere of helium and neon at 20 mm. Hg. pressure.

A theoretical explanation of the asymmetric

conductivity is considered; (1) for the initial state of asymmetry; and (2) for the limiting state of asymmetry, the former referring to the phenomena of ionisation by collision and the latter to the theory of normal cathode current densities.

Typical static characteristic curves are shown, from which can be anticipated the asymmetry shown by the oscillograph records.

Theoretical expressions are given for degree of asymmetry in half- and full-wave rectification, and data collected with reference to the performance of the rectifiers show that the theoretical values are closely approached by this cold cathode type of tube.

SUR L'EFFICACITÉ DES ÉCRANS ÉLECTROSTATIQUES DISCONTINUS (The Effectiveness of Discontinuous Electrostatic Screens).—P. Bricout. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1388–1390.)

A certain number of physical measurements requiring constancy of potential are carried out in metallic enclosures which for experimental reasons cannot be closed completely. The writer investigates the disturbance produced by the discontinuity of the electrostatic screening in a simple case capable of various practical applications. He considers an infinite metallic plane at zero potential. An infinitely long cylindrical wire of radius r is stretched parallel to the plane at a distance a such that r/a is very small (of the order of 1/100 for example). An infinite and infinitely thin metallic plate, parallel to the plane at a distance b ($b < a$) is at zero potential, forming thus an electrostatic screen between plane and wire—which is brought to unity potential. The plate is divided into two parts by a rectilinear gap of breadth $2c$ and unlimited length, whose plane of symmetry passes through the axis of the wire. The writer investigates to what extent the space between plane and plate may be considered as equipotential. To do this, he calculates the potential P on the axis of the gap; this is an upper limit of potential in the region considered. He finds that $P = \dfrac{\log \dfrac{2d + c}{2d - c}}{\log \dfrac{2d}{r}}$, where $d = a - b$ = distance of wire from screen.

NICKEL-IRON ALLOY FOR MAGNETIC CORES.—(German Patent 472623, Felten and Guilleaume Carlswerk, published 4th March, 1929.)

Fine particles of the alloy (containing 5–15 per cent. of nickel) are covered with an insulating layer of acetyl cellulose and are pressed into shape under a pressure not exceeding that of the elastic limit of the alloy.

DER "VARTA-DUPLEX" RADIO-GLEICHRICHTER (The "Varta-Duplex" Rectifying Set for Radio Purposes).—W. Müller. (*Zeitschr. f. Fernmeld:tech.*, 29th April, 1929, V. 10, pp. 55–57.)

An appliance for charging simultaneously both filament and anode accumulators (1 or 2 cells at 1–2 A. and 40 to 60 cells at 80–55 MA.). It includes a rectifying valve with two anodes (one for each type of charging current), an enclosed iron-wire resistance for steadying the 1–2 A. current and a glow-discharge tube which controls the anode battery current.

MAGNETIC ALLOYS OF IRON, NICKEL AND COBALT.—G. W. Elmen. (*Journ. Franklin Inst.*, May, 1929, V. 207, pp. 583–617.)

A full description of the Bell Telephone Laboratories investigations, some of the principal results, and particular applications made.

COOLING OF R.F. IRON-CORED COILS.—(German Patent 470752, Lorenz, published 30th January, 1929.)

For high frequencies the iron core should be run at a very high temperature because of its lower loss at that temperature, whereas the insulated windings should be kept much cooler. According to the invention, a cooling liquid or gas is circulated *between* the iron and the winding.

IMPROVEMENTS IN H.T. INSULATORS.—(French Patent 650934, Verrerie Électrotech., published 12th February, 1929.)

The distribution of potential field in the interior of the insulator is improved by metal coatings on its surface, particularly at the points of contact of the conductors.

DIE ABHÄNGIGKEIT DER DIELEKTRIZITÄTSKONSTANTE TECHNISCHER ISOLIERSTOFFE VON DER FREQUENZ (The Dependence on Frequency of the Dielectric Constant of Commercial Insulating Materials).—P. Böning. (*Zeitschr. f. tech. Phys.*, January, 1929, pp. 20–22.)

An application of the author's ionic absorption theory (Abstracts, 1928, V. 5, p. 523) to frequency-dependence.

ELECTRICAL PRESSBOARDS.—A. R. Dunton and A. W. Muir. (*Electrician*, 10th May, 1929, V. 102, pp. 549–551.)

"Developments which have led to important applications in the manufacture of high-voltage apparatus; improved electrical characteristics; manufacturing processes." To be continued.

SURFACE DISCHARGE AND HIGH VOLTAGE INSULATION.—S. Mochizuki. (*Tech. Rep. Tôhoku Imp. Univ., Sendai*, 1929, No. 2, V. 8, pp. 1–30.)

In English. In the study of surface creepage phenomena in the A.C. field, Nishi found that the surface discharge caused short-wave damped oscillations. The present paper investigates this result quantitatively, extending the research to D.C. The oscillations obtained ranged from 7 to 15 m. wavelength; this wavelength depends on the circuit constants. When a thin layer of air is provided in series with the solid dielectric between the electrodes, much stronger oscillations are obtained than when the electrodes are in close contact with the dielectric. Among the other

points mentioned, it is deduced that the oscillation current may have considerable effect on the spark-over voltage of insulators connected in parallel, whereas it has no effect on the puncture test of thin varnished cambric.

THE INSULATING POWER OF A VACUUM.—N. W. Tomachewsky. (*Arch. f. Elektrot.*, 7th December, 1928, V. 21, pp. 244–249.)

A German paper covering much the same ground as the Russian paper referred to in April Abstracts, p. 222.

"MYCALEX."—(*A.E.G.*, *Mitteilung.*, December, 1928, p. 629.)

An insulating material of mica and glass, made by compression at a high temperature. Its low coefficient of expansion allows it to sustain sharp rises of temperature; in spite of its great mechanical strength it can be machined. It is unaffected by moisture and its dielectric losses are very small.

THE LOSSES IN LAMINATED INSULATING MATERIALS.—W. Burstyn. (*Rev. Gén. de l'Élec.*, 23rd March, 1929, V. 24, pp. 461–463.)

Long French summary of a German paper. In the subsequent discussion Kirch gives the results of his research on ionisation in dielectrics.

ELECTROTECHNICAL INSULATING MATERIALS.—H. Stäger. (*Kolloid Zeitschr.*, September, 1928, V. 46, pp. 60–66.)

A general theoretical paper.

THE NATURE OF DIELECTRIC LOSSES.—H. Schiller. (*Zeitschr. f. Phys.*, No. 7/8, 1928, V. 50, pp. 577–579.)

A vindication of the author's previous statement —that the conductivity conditions, etc., can be explained by an alteration of the limits of the movement of the ions, together with a simultaneous increase in their mobility caused by the high field strength. Smekal has explained the mechanism of such phenomena.

STATIONS, DESIGN AND OPERATION.

A NEW HIGH POWER RADIO BROADCASTING EQUIPMENT.—D. B. Mirk. (*Elec. Communication*, April, 1929, V. 7, pp. 241–257.)

Illustrated description of the International Standard Electric Corporation's transmitter, recently erected and tested at New Southgate, London: with a maximum input of 180 kw., 100% linear modulation was obtained for an aerial carrier power of 50 kw. Wave-range 280–600 m. Modulation is by choke control, at a level slightly higher than the master oscillator output; then the modulated wave is amplified by three stages of high frequency amplification. Various characteristic curves are given. Overall efficiency is about 20%.

IS THE PRAGUE PLAN SOUND?—J. G. Abrahams. (*Wireless World*, 19th June, 1929, V. 24, pp. 638–640.)

THE OPERATION OF SEVERAL BROADCASTING STATIONS ON THE SAME WAVE-LENGTH.—P. P. Eckersley and A. B. Howe. (*Journ. I.E.E.*, June, 1929, V. 67, pp. 772–789.)

After a short history of the development of single-wavelength broadcasting, the paper discusses the general theory and certain experiments carried out by the B.B.C. to test this and to determine empirical quantities. Two stations were used, 38 miles apart working on 491.8 m. Exact carrier-wave synchronisation was obtained by governing the two transmitters from a common source. It was found that with such exact synchronisation, whenever the strength of one station at a point was 5, or more, times that of the other station, reception was normal. If, on the other hand, there was a difference of carrier frequency greater than 5 cycles per second, signals from the one station had to be at least 10 times as strong as those from the other station if good quality was to be obtained. Finally, if the carrier waves are the same but the modulations are different (*i.e.*, different programmes from the two stations), one station must give signals 100–200 times as strong as the other in order to give good service.

The next section deals with the range of stations sharing wavelengths. As no useful estimate of such range can be made (at any rate if the stations are 100 km. or more apart) without allowing for the presence of a strong indirect ray from the interfering station, and as no complete data as to the measured absolute value of the indirect ray are available, a large part of this section is taken up in obtaining a rough estimate of this value. Ultimately, two graphs are given (for perfect and imperfect synchronisation) for the range of two equal-power stations sharing the same wavelength, at various distances apart. The section ends by a consideration of the effect of a number of stations sharing the same wavelength. It is concluded that the range of a station sharing a wavelength with others will not be seriously decreased after more than 6 or 7 stations share the wavelength, because the probability of the averaging out of the peaks of field strength is greater with more stations.

Section 2 deals with the three general methods available for synchronisation; describes why the B.B.C. adopted (for the four sets now working) the method of independent, carefully adjusted transmitters without any common source of master frequency; and how the constant and common frequency at each station is obtained (Eccles' valve-maintained tuning-fork, with 25 valves for amplification and frequency-multiplication). Results of practical working of the four stations are then discussed; these appear to be good. The authors' conclusions are summarised, and a long discussion follows the paper. In their reply, the authors mention that recent reports of Continental reception of one of the four stations (Bournemouth) suggest that distant service from a group of synchronised stations may be better than from a single station: there may be "a better chance for the receiver to piece together the scattered fragments [from the Heaviside layer] of the original pattern." In the discussion itself, Lucas supports piezo-electric frequency regulation as opposed to tuning-forks. Dye, in defending the latter, suggests that

other mechanical oscillators require developing. At the N.P.L., electrostatic drive allows the bars to be relieved from the magnetisation which certainly increases the damping. He describes a simple valve circuit consisting of a valve oscillator having a resonant anode circuit and a resonant grid circuit closely coupled and adjusted so that the anode circuit is approximately harmonic to the grid circuit : a cascade of such units should possess very great stability.

Tableau de Controle des Longeurs d'Onde (Wavelength Control Chart).—(*QST Franç.*, May, 1929, pp. 65–78.)

A number of charts representing the wavelength measurements made from January, 1928 to January, 1929 by the Brussels Laboratory of the International Union of Radio-telephony.

T.S.F. et Éducation (Wireless and Education).—(*QST Franç.*, May, 1929, pp. 5–9.)

An article based on the report of the Hadow Committee.

Amateur Status in Britain.—(*Wireless World*, 19th June, 1929, V. 24, p. 633.)

An editorial on the U.S.A. army-amateur radio organisation (June Abstracts, p. 343) and the lack of any such thing in Britain.

Die Sprache der Amateure (The Language of Amateurs).—R. Wigand. (*Rad., B., F., f. Alle*, June, 1929, pp. 273–277.)

The first list given is the "Amateur Code" giving the German interpretations of English and American abbreviations such as "enuf," "sigs," etc. Then come the Note-quality and Strength of Signal (QSA) codes ; and finally the "Q" code with its subdivisions for general, ship, and aircraft traffic.

GENERAL PHYSICAL ARTICLES.

Die Funkenspannung der Luft bei kleinem Raumquerschnitt (Sparking Voltage of Air for Small Cross Section of Gap).—A. Gyemant. (*Naturwiss.*, 22nd February, 1929, V. 17, p. 135.)

The writer has found evidence that a small cross section of available air-gap increases the sparking potential, just as small electrode distance or small duration of strain increases it.

Sur la Distribution Spatiale du Rayonnement Gamma du Radium dans les Milieux Dispersifs Légers (On the Spatial Distribution of the Gamma Radiation of Radium in Light Dispersive Media).—M. Bruzau. (*Ann. de Phys.*, January, 1929, V. 11, pp. 5–140.)

An exhaustive experimental investigation. Among the results, it is found that the secondary radiation of diffusion in the superficial layers of water leads to the observation of an absorption-coefficient less than the true one : measurements at 10 m. depth give the accurate value, but at smaller depths the rays appear more penetrating than they really are. It is suggested that this effect may vitiate some of Millikan's measurements on cosmic rays.

Messungen über das kurzwellige Ende der durchdringenden Hohenstrahlung (Measurements of the Short Wave End of the Spectrum of the Penetrating Radiation).—E. Regener. (*Naturwiss.*, 15th March, 1929, V. 17, pp. 183–185.)

A preliminary communication on the results of recent tests carried out by the writer with self-registering apparatus.

The Absorption of High-frequency Radiation.—E. C. Stoner. (*Phil. Mag.*, May, 1929, V. 7, No. 45, pp. 841–858.)

Working on the measurements of Ellis and Wooster and of Ahmad, on the gamma rays of *Ra B* and *C*, the author shows that there is agreement within 2 per cent. with calculation provided the Klein-Nishina formula is used, whereas the unmodified Dirac formula gives results 25 per cent. lower than those observed. The effect of filters is considered, and suitable experimental arrangements for more precise tests are briefly discussed. If the Klein-Nishina formula is assumed to hold for the hardest rays, the most penetrating radiation observed by Millikan corresponds to the electron-proton annihilation wavelength, instead of to that of the up-building of the silicon atom as Millikan suggests.

The Temperature Coefficient of Gamma-Ray Absorption.—L. Bastings. (*Phil. Mag.*, February, 1929, V. 7, No. 42, pp. 337–345.)

The somewhat unexpected existence of a temperature effect on gamma-ray absorption was reported in a letter to *Nature* (p. 51, 1927) ; it is confirmed here for a number of typical metals, and an intimate connection, if not an agreement (at present unexplained), is found between the linear temperature coefficient of absorption and the mean coefficient of *linear* (not superficial) expansion of the absorber.

On the Waves associated with β-Rays, and the Relation between Free Electrons and their Waves.—G. P. Thomson. (*Phil. Mag.*, February, 1929, V. 7, No. 42, pp. 405–417.)

Über die Erregung von Reibungselektrizität zwischen Metallen und Nichtleitern in Abhängigkeit vom Druck des umgebenden Gases sowie vom Entgasungszustande des Metalles (The Production of Frictional Electricity between Metals and Non-conductors, in dependence on Pressure of Surrounding Gas and on the Outgassed State of the Metal).—W. Kluge. (*Ann. der Phys.*, 2nd January, 1929, 5th Series, V. 1, No. 1, pp. 1–39.)

Modulation of Light Waves.—A. Bramley. (*Journ. Franklin Inst.*, March, 1929, V. 207, pp. 315–321.)

Description of the experiments referred to in

February Abstracts, p. 114, and discussion of the conclusions to be drawn from them. For H.F. fluctuations in intensity of light waves, by piezo-electric control, see Abstracts, 1928, V. 5, p. 105.

Studien über die Erzeugung von Reibungselektrizität.—L. Wolf. (*Ann. der Phys.*, 19th January, 1929, 5th Series, V. 1, No. 2, pp. 260–288.)

Six experimental conclusions are given which contradict the assumptions made by Riecke and others in their theories of the production of frictional electricity.

Ein Gründliches Experiment über die Kontakt theorie der Triboelektrizität (A Fundamental Experiment on the Contact Theory of Frictional Electricity).—E. Perucca. (*Zeitschr. f. Phys.*, 12th October, 1928, V. 51, pp. 268–278.)

Support for the contact theory is given by the experimental proof of the production of a potential difference by the contact of two insulating materials: it is true that one was a liquid, but the writer considers that there is no reason why a solid-solid contact should show any substantially different result.

A Criticism of the Electron Theory of Metals.—H. M. Barlow. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 459–470.)

Experiments are described which "prove conclusively that the assembly of free electrons in the interior of a conductor invariably behaves like a perfectly incompressible fluid, and consequently in no way resembles a gas. The fundamental hypothesis of the Sommerfeld theory of conduction cannot, therefore, be maintained."

Extinction of an A.C. Arc.—J. Slepian. (*Journ. Am. I.E.E.*, October, 1928, V. 47, pp. 706–710.)

The transition from high conductivity to high resistivity which an A.C. arc undergoes on extinction is studied. Theory, approximate calculations and experimental results are given for the rate of recovery of dielectric strength of the arc space for short arcs.

On the Investigation of Predischarges.—Fr. Trey. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 854–857.)

Photographs taken by means of brush-light show that with long sparks—where the electrode distance is much larger than the radius of curvature of the electrodes—the spark track is produced by the *positive* predischarge.

The Electric Arc in Gases at Low Pressures.—F. H. Newman. (*Phil. Mag.*, November, 1928, V. 6, No. 38, pp. 811–817.)

A type of arc in high vacua was described by the writer in 1926, in which with cold electrodes an arc could be started and maintained provided that an initial electrical discharge was passed between one of the arc electrodes and a third electrode within the discharge-tube; many amperes passed although the pressure was so low that there was practically no luminosity, though the tube walls fluoresced under the cathode ray action. The present paper deals with experiments to investigate the mechanism of this arc and the conditions necessary for its starting.

Conduction of Electricity through Gases. Vol. I.: General Properties of Ions, Ionisation by Heat and Light.—J. J. and G. P. Thomson. (Long review in *Engineer*, 29th March, 1929, V. 147, p. 357.)

The Corona Discharge in Neon.—F. M. Penning. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 632–633.)

Huxley recently found that at the higher pressures the negative discharge (wire cathode) started at a higher P.D. than the positive—which he took as a strong argument against the theory that in corona discharges the electrons are liberated mainly from the cathode by the action of the positive ions.

The writer quotes experiments to show that the effect observed by Huxley is a spurious one occurring only when the gas is not quite pure—that in the pure gas, the starting P.D. is somewhat higher for the positive than for the negative discharge.

High-frequency Discharges in Helium and Neon.—R. L. Hayman. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 586–596.)

Measurements of the potentials required to start and maintain H.F. discharges, of various frequencies, in helium and neon at various pressures in cylindrical tubes of various diameters.

High-frequency Discharges in Gases.—J. S. Townsend and W. Nethercot. (*Phil. Mag.*, March, 1929, No. 43, V. 7, pp. 600–616.)

An account of experiments to determine the relation between the current and the electromotive force in H.F. discharges, and also in continuous current discharges in the same gas (nitrogen) under the same conditions.

Results fit in well with the Townsend theory of the uniform glow in an electrodeless discharge, according to which the mean value of the electric force in the glow of a H.F. discharge should be the same as the force in the uniform positive column of a continuous current discharge.

MISCELLANEOUS.

Die Messung des elektrischen Feldes des Menschen (The Measurement of the Electric Field of Human Beings).—O. Utesch. (*Zeitschr. des V.D.I.*, 27th April, 1929, V. 73, pp. 575–577.)

A description of the apparatus, methods and some results of the work carried out under the auspices of Sauerbruch and Schumann (Abstracts, 1928, V. 5, pp. 349 and 649; *cf.* also v. Ardenne p. 590.) Oxide-coated filaments were discarded owing to the need for absolutely constant emission, and tungsten double-grid valves were used ex-

clusively. All attempts to find magnetic fields were fruitless, but electric field changes were recorded (for muscle actions) both by string-galvanometer and by cathode-ray oscillograph. In the latter case records were taken on a strip of silver bromide paper passing continuously over the outside of the fluorescent screen (10 cms. in from 0.06 to 0.1 second).

PHYSICS IN RELATION TO OIL FINDING (PART I).—A. O. Rankine. (*Nature*, 4th May, 1929, V. 123, pp. 684–686.)

GEOPHYSICAL PROSPECTING: (1) THEORETICAL CONSIDERATIONS, FOR METHODS USING TWO POINT-SHAPED ELECTRODES: by J. N. Hummel; (2) APPLICATION OF ELECTRIC METHODS IN PRACTICAL GEOPHYSICS: by E. Pautsch; (3) MODERN INSTRUMENTS AND METHODS OF SEISMIC PROSPECTING: by C. A. Heiland.—(*Gerlands Beitr.*, 1928, No. 3/4, V. 20, pp. 281–287; *ibid.*, No. 1/2, V. 20, pp. 85–98; *Am. Inst. Mining and Met. Eng. Tech.*, pub. No. 149, 1928.)

LATITUDE DETERMINATION IN AIRCRAFT.—J. Jaumotte, E. Lehay and J. F. Cox. (*Roy. Acad. Belgium*, summarised in *Nature*, 4th May, V. 123, p. 701.)

The magnetic inclination is measured by a telephonic null method depending on the E.M.F. developed in a rotating coil. An accuracy of 10′ is indicated as possible.

EFFECT OF LIGHT ON THE EYE RECORDED BY VALVE METHODS.—E. L. Chaffee. (*Scient. Amer.*, May, 1929, p. 451.)

Fine thread electrodes are connected to the retina of an excised eye, and the electrical effects of light stimulation are amplified and passed into a recording galvanometer.

UNE APPLICATION DES CELLULES PHOTOÉLECTRIQUES À UN DISPOSITIF ENREGISTREUR DE TRAFIC URBAIN (An Application of Photoelectric Cells to the Recording of Urban Traffic).—(*Rev. Gén. de l'Élec.*, 27th April, 1929, V. 25, p. 129B.)

Traffic in the Holland Tunnel joining New York and New Jersey is counted in this manner, the photoelectric impulses being used to work a relay and through this a counting-mechanism.

THE USE OF X-RAYS IN THE TESTING OF ENGINEERING MATERIALS.—(*Elektrot. u. Masch: bau*, 21st April, 1929, pp. 321–352.)

The whole number is devoted to a series of papers on this subject by various authorities.

LA PROPRIÉTÉ SCIENTIFIQUE (Scientific "Property").—Fernand-Jacq. (*Rev. Gén. de l'Élec.*, 12th January, 1929, V. 25, pp. 73–78.)

A report of a conference at Geneva on the subject of better legal recognition of the rights which the originator of a scientific discovery should have in those industrial applications which arise from his discovery. *See also* same journal, 6th April, 1929, pp. 545–549.

GENERAL FERRIÉ. (*Rev. Gén. de l'Élec.*, 30th March, 1929, V. 25, pp. 100B–101B.)

The French Minister of War proposes to pass a special law to retain the services of General Ferrié regardless of the age limit.

UNE MACHINE ÉLECTROSTATIQUE À COURANT CONTINU (An Electrostatic D.C. Machine).—H. Chaumat. (*Comptes Rendus*, 3rd June, 1929, V. 188, pp. 1490–1492.)

Continuing his Notes on the subject (*see* July Abstracts, p. 405) the writer now describes schematically a direct current electrostatic machine which (for one set of values) would deliver 0.2 A. at 20,000 V. maximum. It consists of two insulating discs, one fixed and the other rotating very close to it, each carrying metallic sectors and thus bearing a family resemblance to the Wimshurst machine; but here the sectors of each disc are connected to each other. The fixed set is permanently connected to one pole of a source of d.c. (*e.g.*, a dry battery) and to one pole of the output; the other pole of the dry battery ("exciter") goes to a brush which makes momentary contact with the rotating sectors as they pass, while the other pole of the output goes to a second brush which makes momentary contact with the rotating sectors at moments mid-way between the moments of contact with the first brush. Thus the two sets of sectors form a condenser which is being periodically charged from the exciter and whose capacity periodically changes from a maximum (sectors opposite) to a minimum (sectors staggered). The output mentioned above is calculated for 20 sectors per disc, 50 revs. per sec., exciting volts 1,000, capacity (max.) 0.01 microfarad (obtained by several pairs of discs in parallel) and capacity (minimum) one-twentieth of this.

LES MACHINES ÉLECTROSTATIQUES EN FONCTIONNEMENT SUR DES CONDENSATEURS (Electrostatic Machines acting on Condensers).—H. Chaumat. (*Comptes Rendus*, 10th June, 1929, V. 188, pp. 1546–1547.)

The electrostatic generator referred to above is here considered in conjunction with a condenser acting as a constant pressure reservoir.

ACTION EXERTED BY AN OSCILLATING METALLIC CIRCUIT ON THE GERMINATION OF SEEDS.—G. Mezzadroli and E. Vareton. (*Nature*, 1st June, 1929, V. 123, p. 859.)

Abstract of an Italian paper: the presence of an oscillatory circuit of a single coil 30 cm. in diameter, capable of catching natural cosmic waves* of wavelength about two metres, exerts a favourable influence on the germinating power of seeds, the time of germination being reduced, in some cases, by one half.

* But see Lakhovsky, May Abstracts, pp. 386-387.

Photoelectric Cell as Protection for Electrical Apparatus. (French Patent 653217, Cie. Thomson-Houston, pub. 19th March, 1929.)

Transformers, etc., immersed in oil are protected from over-heating by a photoelectric alarm device. When near the dangerous temperature, the oil in a glass tube becomes permeated with gas, which changes the refraction of a beam of light passing transversely through the tube: this change of refraction diverts the beam from a photoelectric cell and gives the warning.

Train Wireless. (*Wireless World*, 12th June, 1929, V. 24, p. 622.)

A paragraph announcing the formation of a limited liability company in France, called "Radio-Fer," to exploit the installation of wireless on trains. On the next page is another paragraph, describing the broadcast reception arranged by the McMichael Company on the "Flying Scotsman," when the running commentary on the Derby and wireless pictures of the race were received with the train travelling at over a mile a minute.

Erfahrungen über selbsttätige Zugbeeinflussungen (Trials of Automatic Train Control). (*E.T.Z.*, 30th May, 1929, V. 50, pp. 777–780.)

An article on the different systems used on various railroads in the U.S.A.

A Rapid Method for Determining the Limit of Endurance for Bending of Steels, by the Measurement of the Electrical Resistance.—S. Ikeda. (*Tech. Rep. Tôhoku Univ.*, No. 2, V. 8, pp. 42–70.)

Quelques Statistiques réductibles et non réductibles à la Loi de Probabilité simple (Some Statistics reducible and irreducible to the Law of Simple Probability).—R. de M. de Ballore. (*Ann. Soc. Scient. Bruxelles*, V. 48 A, 1928.)

A summary of this paper is given in *L'Onde Élec.*, April, 1929, p. 25A, by P. David, who points out its possible value in the treatment of experimental observations on the propagation of waves.

On the Writing of Scientific Papers.—F. M. Colebrook. (*E.W. & W.E.*, June, 1929, V. 6, pp. 301–306.)

"The preparation and the writing of a paper on even the most severely scientific or technical of subjects is a work of art and should be conceived and executed in that spirit; it should be judged by the same high standards as a work of art, and demands at least as high an endeavour. . . . This æsthetic element . . . can, and should, find expression in all forms of scientific activity—in the devising of experiments, and the designing of apparatus with which to carry them out; in the analysis of data so obtained, and finally in the exposition of the matter for the benefit of others through the medium of the printed word. In all of these there is scope for that perfect adaptation of means to an end, that ordered harmony of parts and economy of effort that finds an immediate response in the æsthetic part of consciousness. I mean the kind of thing that will on occasion provoke the pleased exclamation 'That's very neat,' even from one who has no interest at all in the immediate object of the work." Among the various points whose importance is urged in the paper are:—the isolation of the essential variables of a problem both in analysis and in the design of experiments; the attainment of the highest economic degree of generalisation; the preservation of the "physical anatomy" of a problem in its mathematical formulation; clarity, to be sought not only in the choice of the individual word but also, and more particularly, in the arrangement of the paper as a whole.

Radio Interference.—J. G. Allen. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 882–891.)

"The radio interference situation is rapidly becoming so serious as to make improvements in both methods of detection and methods of elimination absolutely imperative." Of the interference cases brought during one year to a certain Power company as being due to their supply, the following percentages of true causes were traced:—15% defective receivers and associated apparatus; 13% miscellaneous; 30% industrial apparatus; 25% household appliances; 17% Light Company's equipment. A figure is given showing aerial and earth conditions "typical of those found in half the homes to-day," twelve different avoidable sources of trouble being indicated.

The most effective method in interference detection is that combining the good features of the intensity method (using substantial and reliable audibility meters of the indicating type, possessing high sensitivity) with the circuit-selection features of the directional method, coupled with extensive experience both in the field and in the laboratory. Progress should be made in more thorough filter design study, with special attention to draining the noises from power lines, trolley wires, feeders and telephone lines; and in the manufacture of "interference proof" electrical appliances.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

TELEVISION SYSTEMS.

Convention date (U.S.A.), 6th April, 1927. No. 302238.

A television system is described, the novelty of which lies in the feature that the field scanned at the receiving station is evenly illuminated over its whole area. A subordinate feature is that the field is at least as large as the picture to be viewed, the instantaneous intensity of illumination being varied in accordance with the tone value of the exposed elemental area of the picture at any instant.

No. 288237 of the same Convention date. Here a system for translating space-variations of light intensity into time-variations of electric-current energy is characterised by the provision of a network circuit having an attenuation factor designed to correct for the distortion arising from the fact that the light-aperture in the rotating scanning disc has finite dimensions instead of being a mere point.

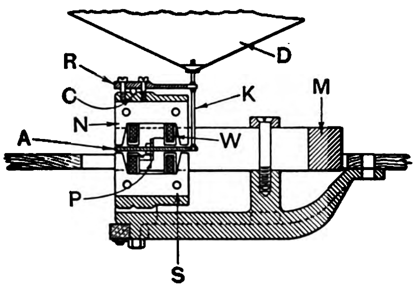
No. 288238 of the same Convention date. The object is scanned by a beam of intense light which is moved rapidly so as to give a cyclic point-by-point exploration, the reflected ray being received directly on a light-sensitive cell of large aperture, without having to pass through any obstruction, such as a condensing lens.

Patents issued to Electrical Research Products Inc.

LOUD SPEAKERS.

Application date, 8th November, 1927. No. 305614.

A balanced armature *A* is pivoted centrally on a blade *P* mounted across the centre of the gapped pole-pieces *N*, *S* of a magnet *M*. The armature is rocked about the blade *P* under the influence of currents flowing in the coil windings *W*. A thin rod *K* connects one end of the armature to a stiff



No. 305614.

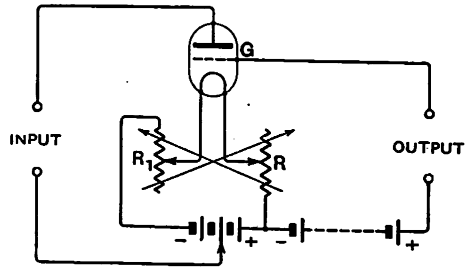
reed *R* having a very high natural period of vibration, preferably exceeding 10,000 cycles per second. The reed is forced by two screws against a rod *C* resting in a groove or notch formed in a rigid part of the mounting, this arrangement allowing the reed to be correctly centred. The loud speaker diaphragm *D* is mounted on the rod *K* at a point beyond its connection to the reed *R*. Owing to the reed control being located at a point outside the region embraced by the magnet poles, the cross-section and mass of the armature can be considerably increased without giving rise to distortion.

Patent issued to C. Mahé de Chenal de la Bourdonnais (Prince de Mahé).

VALVE AMPLIFIERS.

Application date, 16th January, 1928. No. 309846.

For low-frequency amplification, the grid *G* is maintained at a high potential relative to the plate and filament. The input is applied across the plate and filament, whilst the output is taken from the grid. The arrangement is stated to be advan-



No. 309846.

tageous because the impedance across the short grid-filament space is comparatively low, and can therefore be more nearly equated to the impedance say of a gramophone pick-up. A separate filament rheostat R, R_1 is provided for each leg, the two being varied inversely so that the mean operating potential of the plate can be adjusted without changing the total resistance included in the filament circuit.

Patent issued to A. F. Pollock and D. A. Pollock.

COATED CATHODES.

Convention date (Austria), 30th April, 1927. No. 289763.

Relates to a process for the deposition of an alkali-earth metal, such as barium strontium, or calcium on to a filament wire of platinum-copper, nickel, or chrome nickel. Vapours of the alkali metal are liberated by a reduction process (initiated by heating) from a mixture of barium, strontium, or calcium oxides, together with calcium or magnesium as a reducing agent. The mixture is formed into a small rod which is attached to the inner side of the anode—*i.e.*, the side next to the cathode. The bulb is then exhausted and the electrodes heated by high-frequency currents in the known manner.

Patent issued to Vereingte Gluhlampen und Electricitats A.G.

THERMIONIC RELAYS.

Convention date (France), 18th November, 1926. No. 280948.

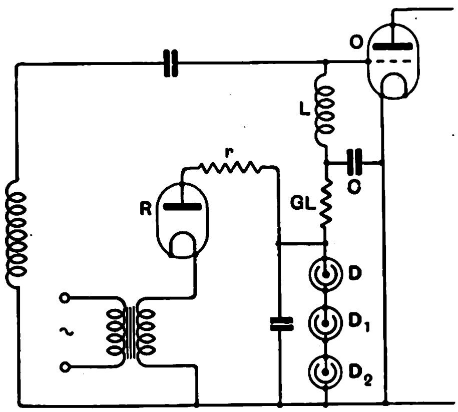
A thermionic relay suitable for use in distant-control systems, for radio communication, or for television, comprises a glass vessel containing neon or helium gas or mercury vapour under low pressure and arranged to have two discharge paths. The first or main discharge takes place between an anode located at one end of the tube and a transverse set of electrodes located at the other end of the tube. The second or auxiliary discharge takes place across a heated filament, a control grid, and a plate grouped together at one end of the tube, and forming the transverse set of electrodes above mentioned. The input is applied between the grid and filament of the transverse electrodes, and initiates a local or auxiliary discharge between the heated filament and plate. The consequent ionization breaks down the gap between the transverse set of electrodes and the distant anode, and allows a main discharge to set in along the length of the tube.

Patent issued to G. Valensi.

VALVE OSCILLATION-GENERATORS.

Application date, 19th March, 1928. No. 308085.

In order to maintain a safe negative bias on the grid of a power oscillator, even during non-oscillatory periods, the grid circuit is provided with one or more discharge tubes D, D_1, D_2, the "threshold" value of which is at least equal to the required grid bias. In parallel with the discharge tubes is a rectifier R and series resistance r capable of producing an electromotive force of the same threshold value. So long as the generator O is developing oscillations, the grid condenser C is charged up to the required biasing voltage, any excess leaking



No. 308085.

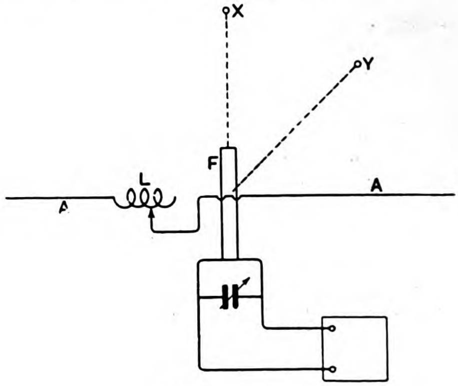
away through a choke L, high resistance GL, and the discharge tubes D—D_2. Should the oscillator cease to function, the negative charge on the grid is maintained at a safe value by the rectifier R, which may be replaced by a battery.

Patent issued to S. G. S. Dicker.

DIRECTIONAL WIRELESS.

Application date, 11th April, 1928. No. 307237.

In order to increase the directional effect of a frame aerial, particularly in a commercial installation of the kind in which two stations are kept permanently in tune and are normally intended only to communicate with each other, means are



No. 307237.

provided to mitigate the effect on the receiving frame of any signals coming from directions other than that to which the frame is orientated.

As shown in the Figure the frame F is set in line with its companion station at X. A long horizontal wire A, having a tuning coil L, is arranged at right angles to the frame. This has no effect upon signals from station X since it is symmetrically disposed to the latter. Its effect upon signals from an interfering station such as Y, is to distort or guide the incoming wave so that its front is shifted more into line with the wire A, where it has less effect on the frame aerial F than if it maintained its normal direction.

Patent issued to L. Mellersh-Jackson.

ELECTRIC PICK-UPS.

Application date, 9th December, 1927. No. 307767.

The vibrating reed is pivoted substantially at a point which is an anti-node of the fundamental vibration, or is otherwise mounted so as to have a relatively free rocking motion about that point. The fundamental, and certain of the overtones, are thereby largely damped and a more even tone response is secured.

Patent issued to P. Wilson.

Application dates, 16th December, 1927, and 25th January, 1928. No. 307971.

The vibrating reed is so mounted between the opposite poles of the magnet that no flux normally passes through it, *i.e.*, it normally lies midway between and transversely of the poles. Under the impulse of the stylus needle it moves towards one pole and away from the other.

Patent issued to A. E. Barrett.

MAINS-SUPPLY UNITS.

Application date 22nd December, 1927. No. 305771.

In practice it is often found that as soon as an earth-connection, even if made through a condenser, is introduced at the input end of a multi-valve receiver fed from a mains-supply unit, "noise" is apt to arise although the installation may work quietly so long as it is unearthed. According to the invention this defect is eliminated by inserting, between the mains and the standard filter circuit, a double choke consisting of a winding in series with the positive and a second winding in series with the negative main, the two windings being closely coiled around the same magnetic core in such sense that the supply and return currents flowing in the main leads neutralise each other and produce substantially no flux in the core.

Patent issued to R. E. H. Carpenter.

ELECTROLYTIC RECTIFIERS.

Application dates, 13th January and 12th November, 1928. No. 309622.

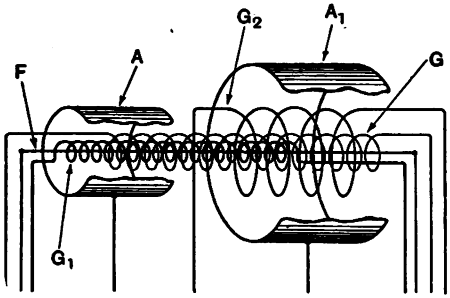
An electrolytic rectifier or "valve" comprises a cathode containing tungsten alloyed or combined with cobalt, iron, aluminium, or tantalum. The electrolyte consists of ammonium phosphate (30 per cent. solution); tartaric acid (20 per cent. solution) to which is added a small quantity of salicylic acid; and boric acid (3—6 per cent. solution); the whole being electrolised. The anode is of aluminium.

Patent issued to S. D. White and R. J. Jones.

A DUPLEX VALVE.

Convention date (France), 10th August, 1927. No. 295351.

A long single-wire filament F is surrounded by two spiral wires, G, G_1, forming a space-charge grid and a control grid respectively. Two separate cylindrical anodes, A, A_1 are spaced apart from each



No. 295351.

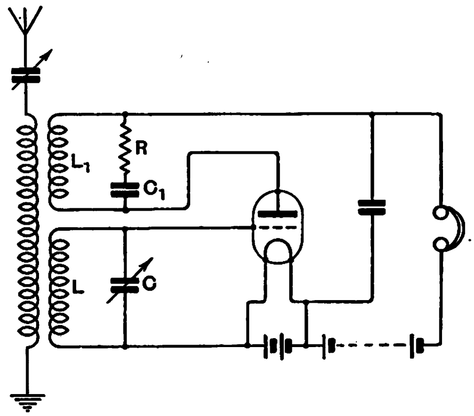
other along the length of the filament. One anode is of smaller dimensions than the other so that for the same value of H.T. applied to both anodes, the current taken from one is less than that from the other. The smaller anode can then, for instance, be used to provide the local oscillations in a super-heterodyne receiver. A third grid G_2 may be interposed in the space between the control grid and the larger anode.

Patent issued to Soc. des Etablissements Industriels de E.C. et de Alexandre Grammont.

CONSTANT COUPLING RECEIVERS.

Convention date (U.S.A.), 3rd January, 1927. No. 283121.

In order to maintain the degree of back-coupling constant, irrespective of the particular signal-frequency being received, the plate coil L_1



No. 283121.

is shunted by a resistance R in series with a condenser C_1. As the input circuit L C is tuned to a higher frequency, thus tending to increase the coupling-factor, this tendency is automatically offset by the action of the shunt circuit R C_1 in diverting a larger proportion of the total plate current from the coupling-coil L_1. For lower frequencies the proportion of plate current by-passed through the shunt circuit decreases.

Patent issued to The British Thomson-Houston Co., Ltd.

MAGNETOSTRICTIVE OSCILLATORS.

Application date, 3rd January, 1928. No. 283116. (Original Convention date, 4th January, 1927.)

A system for generating oscillatory currents comprises a magnetostrictive vibrator, *i.e.*, a core of nickel, nickel-steel, or other metal or alloy, resting freely on or clamped to a support and surrounded at each end by exciting windings. The resulting mechanical vibrations set up in the core by magnetostrictive action may vary from hundreds to hundreds of thousands of cycles per second, according to its shape, mass, and elasticity. Resonance occurs at a fundamental and at harmonic frequencies. The movements of the vibrator may be used to modulate a local current, which may in turn be back-coupled with the exciting windings so as to produce sustained oscillations of a frequency determined by the natural magnetostrictive period of vibration.

Patent issued to G. W. Pierce.

MULTI-STAGE VALVES.

Convention date (Germany), 18th December, 1926. No. 291735.

In a multi-stage valve arranged for heterodyne reception, a piezo-electric crystal is mounted within the same evacuated bulb, between the plate circuit of the first detector stage and the grid of the first intermediate amplifier. This allows sharp tuning in a system which is normally resistance-coupled, and ensures a corresponding gain in selectivity.

Patent issued to W. Kunze and Radiofrequenz G.m.b.H.

SOUND DIAPHRAGMS.

Application date, 2nd December, 1927. No. 307106.

The vibrating diaphragm of a loud speaker or telephone earpiece is provided with one or more short-circuited conductors, inserted in holes specially bored in the diaphragm. Or the armature may be cut out into the form of a reed or a star, and short-circuited copper bands wound around one or more of the limbs. These damping elements tend to stabilise the magnetic flux and increase sensitivity.

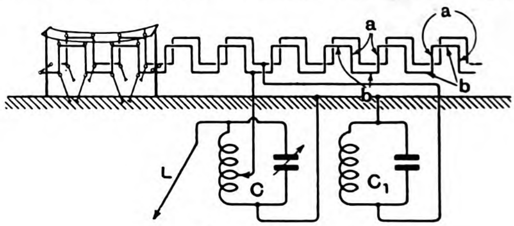
Patent issued to British Thomson-Houston Co., Ltd., and A. P. Young.

AERIAL SYSTEMS.

Application date, 7th December, 1927. No. 307446.

A directional broadside aerial is built up of interconnected active and non-active elements, forming a zig-zag grid. For unidirectional working the aerial is backed by a second similar structure acting as a reflector. The active elements *a* are vertical, whilst the inactive elements *b* are horizontal and serve merely to complete a transmission line for the feed currents, which are supplied by a one-wire power cable *L*. The speed at which the supply currents are distributed over the whole aerial system is apparently infinite, so that the currents in all the vertical or active elements are in phase, and the radiation is in the form of a current sheet.

In order to secure this result the vertical and horizontal elements must be of the same order of magnitude, whilst the sum of the length of a vertical and horizontal element is an odd multiple



No. 307446.

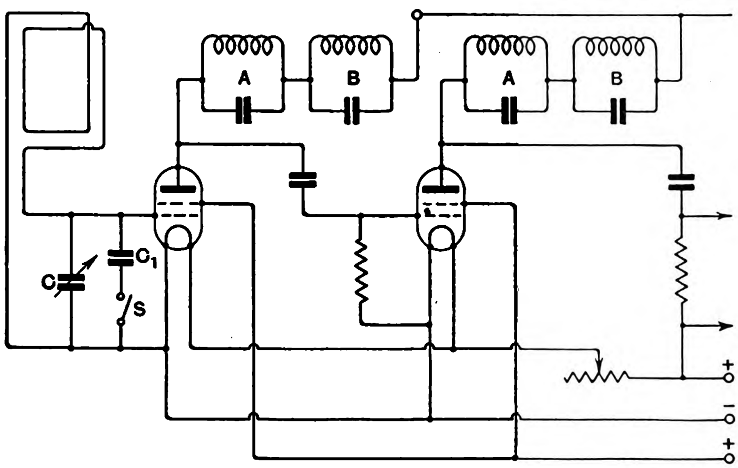
of half the working wavelength. Finally the length of each horizontal is chosen so that the induced currents in each of the verticals are in phase. The centre of the aerial system as a whole is earthed through a tuned loop circuit *C*, the reflector system being similarly grounded through a tuned circuit C_1.

Patent issued to Standard Telephones and Cables, Ltd.

SWITCH-TUNED RECEIVERS.

Application date, 10th October, 1927. No. 307519.

The circuits are arranged so that reception from a given short-wave station can be changed to a long-wave programme by the mere operation of a switch, without further tuning adjustment. The invention is illustrated as applied to two stages of screened-grid amplification to be followed by the usual detector and L.F. stages. The plate circuit of each valve comprises two circuits *A*, *B* tuned respectively to the selected short and long wave stations it is desired to receive. Owing to the difference in wavelength, the circuit *B* offers very little impedance to currents to which the circuit *A* is resonant, and *vice versa*.



No. 307519.

The actual selection between one programme and the alternative is determined by the switch *S*. In its open position as shown, the condenser *C* automatically tunes the frame aerial to the short-wave station, to which the plate circuits *A* are also permanently tuned. In this case the circuits *B* are ineffective. When the switch *S* is closed, to bring a parallel condenser C_1 into circuit, the receiving frame is automatically tuned to the long-wave station, and co-operates with the circuits *B*, the circuits *A* having practically no effect on the strength of the received signals.

Patent issued to British Thomson-Houston Co., Ltd. and T. H. Kinman.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. SEPTEMBER, 1929. No. 72.

Editorial.

The Marconi Licensing Settlement.

IN our July issue, on page 368, we reported briefly that the Marconi Company had won a High Court appeal against a decision of the Comptroller-General of the Patent Office, under which royalties in respect of the use of Marconi patents for the construction of broadcast receiving apparatus were to be reduced from the usual basis of 12s. 6d. per valve stage to 10 per cent. on the wholesale selling price of a receiver, subject to a minimum charge of 5s. on the first valve and 2s. 6d. on each additional valve stage.

The success of the appeal in the High Court entitled the Marconi Company to claim the full royalty on the old basis of 12s. 6d. per stage on all apparatus sold by licensees since the case for a reduction came up before the Comptroller-General of the Patent Office in August of last year. Since many manufacturers had been over-confident that the decision of the Comptroller would stand, they had not made provision for the possibility of having to pay royalties on the old basis, and the Radio Manufacturers' Association, as representing the licensees, got into touch with the Marconi Company immediately the High Court decision was made known, with the object of trying to arrive at some compromise to relieve the trade of the burden of having to pay the full royalties retrospectively.

As we go to press we understand that the Marconi Company has agreed to a new licence on a five years' basis under which royalties will be 5s. per valve stage on all apparatus, whether such apparatus includes Marconi patents or not, and in respect of mains eliminator apparatus as a battery substitute for use with broadcast receiving apparatus the royalty to be 5s. The main heads of the new agreement are given on page 485.

Such an arrangement is, we consider, a compromise in every sense of the word. It is distinctly to the advantage of the Marconi Company that they should be able to guarantee a revenue over five years from patents which have already earned substantial revenue and some of which are due to expire during this period of five years or have already expired. The trade, on the other hand, also gains substantially, since they are relieved of the burden of having to pay at the rate of 12s. 6d. per valve stage as from August of last year up to the time that their present agreement would be due to expire. The present royalty of 5s. per valve-holder will, in many instances, be more advantageous to the licensee than the terms laid down in the decision of the Comptroller-General of the Patent Office, against which the Marconi Company appealed.

The Frequency Departure of Thermionic Oscillators from the "LC" Value.

By Instructor-Lieutenant S. W. C. Pack, A.C.G.I., M.Sc., R.N.

SUMMARY.

The article gives an account of work carried out at the City and Guilds (Engineering) College under the supervision of Professor C. L. Fortescue, M.A., and Professor E. Mallett, D.Sc., during 1927. It describes investigations in the departure of the frequency of valve oscillators from the "LC" value under varying conditions of grid coupling, grid bias, filament current, anode voltage and added resistance in the oscillatory circuit, the investigations being made by a new method. The work is divided into the following sections :—

Section I.—Introduction and general outline of the scheme with comparison of previous work on measurements of frequency variation of thermionic oscillators.

Section II.—Exact procedure and various refinements in the proposed method of investigation.

Section III.—The comparison of the maintained tuning fork frequency against standard time as given out by Greenwich time signals.

Section IV.—The frequency departure from the "LC" value is here dealt with fully. The theory of the frequency of oscillations is given first neglecting and then considering grid current. The expected accuracy of results is estimated and it is found that while the frequency variation is measurable to a very high degree of accuracy, about 1 in 40,000, the measurement of the actual departure from the "LC" value is somewhat uncertain owing to the smallness of this term in comparison with the possible error obtained in measuring the values of L and C. Curves of results obtained with varying conditions such as grid coupling filament current, anode voltage, etc., are given and are explained in the light of the theory. The frequency departure on the average varied between about 110 beats per minute to 160 beats per minute below the "LC" frequency, *i.e.*, the frequency variation was 50 beats per minute (almost 1 cycle per second), about an average departure of $2\frac{1}{2}$ cycles per second below the "LC" frequency. In most cases the variation was much smaller than this, about $\frac{1}{2}$ cycle per second, but in the case of adding resistance to the "L.C." circuit the frequency departure increased from 150 beats per minute to 260 beats per minute below the "LC" frequency, *i.e.*, a frequency variation of about 2 cycles per second. The "LC" frequency was about 640 cycles per second. In a practical case with a combination of small variations in the conditions due to batteries running down, etc., the frequency would probably increase by about $\frac{1}{2}$ cycle per second, *i.e.*, about 8 parts in 10,000 or 0.08 per cent.

Section V.—Criticism of the research work in general. The method has proved to be effective and the results obtained form a good groundwork for further research on the subject. Arising from experience gained in the work, various suggestions are put forward for further research on the frequency variation of valve oscillators.

I. Introduction.

THE thermionic valve adapted as a generator of oscillations has the advantage of being able to give any desirable frequency within limits; these oscillations are controllable to a fair degree of accuracy by variations of the values of the inductance L and the capacity C of the oscillatory circuit. To a very much smaller extent the frequency of these oscillations also depends on the ohmic resistance of the oscillatory circuit, the anode resistance of the valve, the filament current, the anode voltage, and the coupling between the grid and anode coils. It is our purpose in the present investigation to keep L and C of the oscillatory circuit constant and thus fix what we will henceforth refer to as the "LC" frequency, f_0, at a constant value

$$f_0 = \frac{1}{2\pi\sqrt{LC}},$$

and by changing the conditions such as anode voltage or grid coupling whose effects we want to investigate, to vary slightly the actual frequency f of the oscillator. It is these variations that we want to determine

In previous experiments in the frequency variation of thermionic valve oscillators

(i) and (ii), the exact frequency departure has not been measured. Instead, the frequency has been kept constant at some value by making small changes in the capacity of the oscillatory circuit as the conditions are varied. The advantage of the present method is that the frequency differences themselves are actually measured, the capacity and inductance of the oscillatory circuit being kept constant as in a practical case. The usual trouble underlying the determination of small frequency differences is the sudden tendency for two frequencies to "lock" into one frequency as they approach a common value. This tendency to lock is avoided in these experiments, as explained later.

The actual frequency f of the oscillator will differ from f_0 by an amount depending on the factors mentioned above, viz., grid coupling, grid bias, anode voltage, filament current, and resistance. To determine $(f_0 \sim f)$, the departure of frequency from the "LC" value, we must determine f experimentally and calculate f_0 from the known L and C values. To determine f the oscillator frequency, we must produce beats between it and a known frequency and so deduce f by counting the beats: whether f is above or below the known frequency can easily be determined by slight capacity increases in the oscillator, thus reducing f and indicating whether beats should increase or decrease. In the present case, the "LC" values were arranged to give an f_0 which was exactly equal to the known frequency (*i.e.*, a tuning fork harmonic) and so the beats between the known frequency source (of frequency f_0) and the oscillator (of frequency f) gave the frequency departure $(f_0 \sim f)$ direct.

II. Proposed Method of Investigation.

Before we can make any satisfactory measurement on frequency variation, we require to have some reliable source of constant frequency. The smaller our measurement of frequency drift is to be the more nearly constant must our frequency source be. We naturally turn then for our frequency standard to the tuning fork. To maintain it, it is proposed to adopt the method first suggested by Eccles (iii), *i.e.*, by using a thermionic triode and connecting up as described in a previous article (iv). From some part of the tuning fork circuit it is proposed to take a supply to an amplifier employing fairly high grid bias so as to introduce many harmonics and then produce in a loud speaker or telephone a note rich in harmonics of a fundamental frequency exactly equal to the tuning fork frequency. We now have our constant frequency supply, but the frequency so far is not accurately known. To determine the frequency, a synchronous motor or phonic wheel is to be synchronised with the tuning fork frequency through a system of amplifiers from the fork circuit, and by running for a long period of time with a train of dials recording the revolutions, will indicate relatively to some scale the frequency of the maintained tuning fork. The exact procedure and various refinements for ensuring accuracy have been dealt with in a previous article mentioned above.

We will now suppose we have developed our known constant frequency source and are ready for our oscillator experiments. If a loud speaker is inserted in the oscillator circuit we can beat the oscillator frequency against the tuning fork frequency or one of its harmonics. The conditions in the circuit of the valve oscillator may now be varied as required, L and C being kept constant, and the variation in the frequency determined by the alteration in the number of beats. The fact that the oscillator circuit and tuning fork circuit are isolated from one another prevents any locking into a common frequency which might otherwise occur.

The foregoing method appears to be quite straightforward, but actually the constant frequency source gave more trouble and waste of time than one would expect. In the first place maintaining a low-frequency fork by a thermionic valve is no easy matter and requires careful study and design of the operating circuit. Assuming the fork to be maintaining satisfactorily, the next problem is to synchronise the phonic wheel, and there is a large degree of uncertainty in accomplishing this feat.

(i) *Royal Soc. Proc.*, 96, pp. 455–465.
(ii) *Royal Soc. Proc.*, 108, pp. 216–231.

(iii) *Phys. Soc. Proc.*, Vol. 31, 1919.
(iv) *E.W. & W.E.*, Sept., 1927, "A Constant Frequency Source."

III. The Exact Frequency of the Maintained Fork.

(a) *Comparison with Greenwich time signal.*

After much preliminary work the tuning fork maintained strongly, and the synchronous motor pulled into step satisfactorily, so preparations were made to determine accurately the frequency of the maintained tuning fork. The number of vibrations made by the fork were recorded by the dials to a known reduced scale as already referred to, and it was only required therefore to determine the exact number occurring during some definite known period of time. The standard of time used was the College electric clock (checked up by Greenwich time signals). During the test the eye of the observer had to be kept on the dials of the synchronous motor, so it was essential therefore to convey by sound, to the observer, the exact instant at which to make his observation. To accomplish this, two leads were connected across the series coil of one of the electric clocks and connected to the high-resistance side of a small telephone transformer to safeguard against shorting the series coil. The other side of the transformer was taken to a pair of phones in the room where the observations were being made, and here one could listen to the half-minute ticks of the electric clock, while watching the synchronous motor dials. A stop watch set at the same time as the electric clock gave some indication of the approach of the tick of the clock, and also indicated the particular minute of the hour at which the reading was taken. The stop watch acted as a sort of rough adjustment, and the click in the phones provided the fine adjustment. The fork and motor were run for several hours so that an accurate measurement could be made. Five consecutive readings at minute intervals were taken at the commencement of the trial so as to get a good mean figure for the dial reading corresponding to a given instant. Similarly at the end of the trial five consecutive readings were taken and the mean value obtained. Actually intermediate readings were taken in the same way during the whole of the trial at various periods, for it was never certain when the motor would not pull out of step and slow down. Graphs were plotted of the initial readings and the final readings with the idea of getting the initial and final mean reading quite accurately, but it was found that the dial readings themselves had been taken really accurately and could be relied upon to $\frac{1}{20}$ of a unit after some practice. From this we can get some idea of the accuracy in a five-hour test. There is an initial and final reading, the latter to be subtracted from the former. This figure we can rely upon to about $2 \times \frac{1}{20} = \frac{1}{10}$ of a unit.

According to the scale of reduction, on the dial $\frac{1}{10}$ unit corresponds to $20 \times 12 \times \frac{1}{10}$ vibrations of fork, *i.e.*, the possible error in five hours is 24 vibrations of fork.

The total number of vibrations in five hours is about $5 \times 60 \times 60 \times 128$, so our error is of the order

$$\frac{24}{5 \times 60 \times 60 \times 128} \times 100\,\% = 0.001\,\%$$

or 1 in 100,000 approx.

The readings at various instances were tabulated and initial and final mean readings obtained for calculation.

Temperature of room = 67.5 deg. F.
Temperature of fork = 64.1 deg. F.

Our initial mean reading is 275.84 at 11.16 a.m.

Our final mean reading is 9,696.75 units at 4.11 p.m. By subtraction we get 9,420.91 units in 295 minutes.

Hence vibrations per second $= \frac{9{,}420.91 \times 4}{295}$

Frequency of maintained fork
$= 127.741_{15} \ldots$ at 64.1 deg. F.

(*b*) *Remarks.*

We have seen that the resultant frequency value could be relied upon to within 1 part in 100,000. This was borne out in the actual result for it was found that all values estimated over a three-hour period gave the figure 127.741. . . Over a three-hour period we should expect an accuracy of 2 in 100.000 and over a one-hour period 5 in 100.000. The following figures were actually deduced :—

Three-hour period (11.33 a.m. to 2.14 p.m.) . . . 127.7396 . . .

One-hour period (2.14 p.m. to 3.14 p.m.) . . . 127.7445 . . .

We may, therefore, assume that at a

constant temperature the frequency of the fork varied a negligible amount, so we may rely upon the frequency as determined, 127.741 . . . at 64.1 deg. F.

It would have been interesting to determine the frequency variation with temperature variation, but so much time had already been taken up with the constant frequency source that it was considered advisable to proceed with the oscillator experiments. Additional apparatus would have been necessary for varying temperature, and much time taken up. Hence in the absence of any further investigation on valve maintained tuning forks (especially low-frequency forks), we must accept the results established by D. W. Dye for a high-frequency fork (1,000 cycles), viz., 1 deg. C. increase in temperature causes a decrease in frequency of 1.15 parts in 10,000.

and ran all right, but, unfortunately, no time was left available in which to investigate and explain the cause of this change in conditions. A frequency reading was taken which lasted 2½ hours, and following that the research work ended. It is mentioned here, however, in view of the large frequency change probably brought about by removing the earth connection.

The result of the 2½ hours' trial gave a frequency of 127.968_{44}. . at temperatures :—Fork temperature 68.65 deg. F. Room temperature 69.72 deg. F.

Expected decrease in frequency from the previous measurement due to increase of fork temperature would have been, according to Dye's figure, as follows :—

$$\frac{100\ (68.65 - 64.1)}{180} \times 1.15 \text{ parts in } 10{,}000,$$

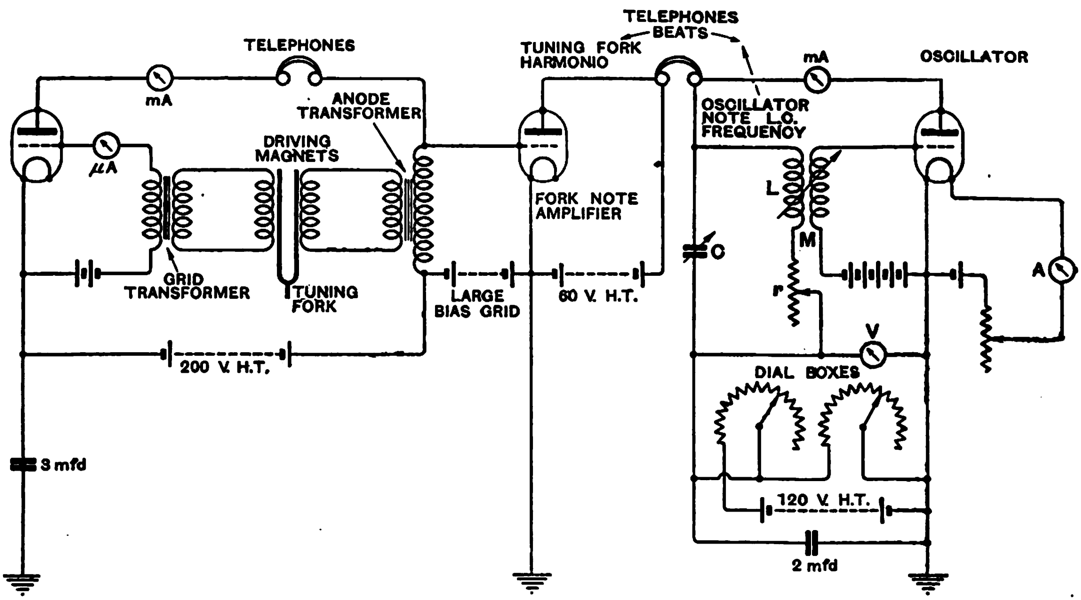

Fig. 1.—*Beats in headphones between tuning fork harmonics and oscillator note.*

Actually, about six weeks later, when the normal temperature was much higher, a frequency determination was made after the oscillator work had been done. It was then found, however, that the motor would not synchronise under the previous conditions, and the measurement was taken with the earth connection to the fork circuit disconnected. The motor then synchronised

i.e., 2.9 parts in 10,000, or 3.7 parts in 12,774, and we should expect a frequency of

$$127.741_{15} \ldots - 0.037 = 127.704\sim.$$

We may look, therefore, upon the difference between the unearthed and earthed conditions, in the absence of further information, as being responsible for a frequency

change of $127.968_{44}.. - 127.704$, *i.e.*, 2.64 parts in 1,000, which shows that we must be extremely careful to keep the earthing arrangements of the constant frequency source always the same. It would be interesting to see the results of experiments in this direction made at constant temperature, that is using a maintained fork of non-expansible alloy and a really constant temperature cell.

IV. Frequency Departure from the Theoretical "LC" Value.

(*a*) *Arrangement of Oscillator and Constant Frequency Source.*

The diagram of connections in Fig. 1 indicates the arrangement for obtaining beats between the oscillator and the constant frequency source.

The oscillator used in these experiments was a low-frequency tuned anode oscillator, with tappings on the anode coil, and may be seen in the photograph in Fig. 2. The grid coil, which also has tappings, can be seen supported on the central wooden shaft and is capable of sliding on this shaft to regulate the coupling between it and the anode coil. The anode coil is in sections, the taps at each section being brought out to the row of brass terminals seen on the side of the box. The valve holder and grid bias batteries were housed inside the box; the remaining apparatus, including condensers, coils, meters, and additional apparatus for the test, were arranged outside the box in the most accessible manner. The wooden shaft, on which slides the grid coil, is marked in cms., commencing from the right-hand end at zero. The position of the grid coil relative to the fixed anode coil can then be noted by referring to these figures on the shaft. The figure quoted is that which is flush with the right-hand end of the cylinder on which the grid coil is wound. When the grid coil is just clear of the anode coil the figure is 0 cms., and when the grid coil is completely within the anode coil the reference figure is 23.8 cms. The oscillator was connected up as indicated in Fig. 1. The valve used was a Marconi D.E.R. The high-resistance dial boxes across the 120-volt H.T. supply were for the purpose of varying the anode voltage. The resistance "*r*" was a special variable high-frequency non-inductive resistance box of the plug-in type made by Gambrell, for the purpose of inserting resistance in the oscillatory circuit. The condensers were a 1,000 jar, 8 jar, and 1 jar, Navy pattern, all in parallel. These all had to be calibrated in position.

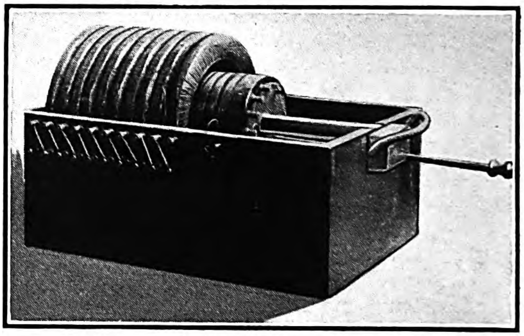

Fig. 2.—*L.F. oscillator under test.*

A filament resistance was inserted for the purpose of reducing the filament current, an ammeter inserted recording the latter. One headphone of a pair of headphones was connected in the anode circuit. The whole of this apparatus was on a different bench from that of the constant frequency source, and all the batteries were entirely distinct.

The connections to the constant frequency source may also be seen in Fig. 1. As in the case of the frequency determination supply was taken from across the transformer winding in the anode circuit of the maintaining valve, to an amplifier. The amplifying valve used was a D.E.5B., so that with a good grid bias the steep slope and cut-off characteristic of this valve could be made to distort the wave form, and produce a note rich in harmonics. The other headphone of the pair of headphones recently mentioned was now connected in the anode circuit of the amplifier, and thus produced a note whose fundamental frequency was exactly that of the maintained tuning fork and whose harmonics were exact multiples. The observer can now listen to beats between the oscillator and tuning fork by wearing the headphones, and in this way he is able to determine accurately the frequency of the oscillator at any time by comparison of known frequency of the constant frequency source.

The procedure in detail is described in sub-section (*c*). We now turn to the theoretical side of valve oscillator frequencies.

(*b*) *Theory of Valve Oscillator Frequencies.*

List of Symbols :—

L = Inductance of anode coil in oscillatory circuit.
C = Capacity of anode coil in oscillatory circuit.
R = Resistance of anode coil in oscillatory circuit.
L_1 = Inductance of grid coil.
R_1 = Resistance of grid coil.
μ = Amplification factor.
R_a = Anode resistance of valve.

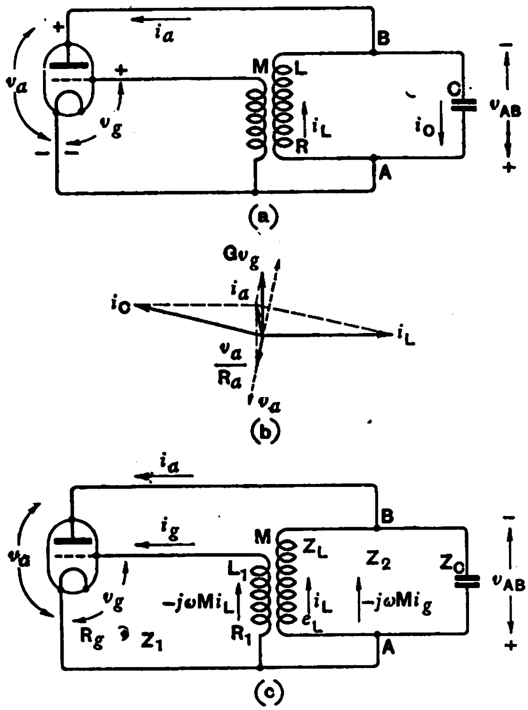

Fig. 3.—*Anode circuit oscillator theory.*

G = Grid conductance.
M = Mutual inductance between grid and anode coils.
I_a = Steady anode current.
V_a = Steady anode potential.
V_g = Steady grid potential.
i_a = Oscillating component of anode current.
v_a = Oscillating component of anode potential.
v_g = Oscillating component of grid potential.
i_L = Oscillating component of current in L.
i_C = Oscillating component of current in C.

The following theory neglecting grid current is due to Prof. C. Gutton, of Nancy. A further theory which considers grid current due to Prof. C. L. Fortescue will then follow.

Let us consider the sinusoidal variations about the steady values. These may be represented by the vectors, as shown in the vector diagram in Fig. 3 (*b*). The circuit is shown in Fig. 3 (*a*).

$$i_a = i_L - i_C,$$

also $$i_a = \frac{v_a}{R_a} + G \,.\, v_g$$

$$i_aR_a = v_a + \mu v_g.$$

Now $$v_a = -v_{AB}$$
$$= i_LR - \frac{di_L}{dt}L$$
$$= -i_L(R + DL), \text{ where } D \equiv \frac{d}{dt}$$
$$v_g = -\frac{di_L}{dt}\,.\,M.$$
$$= -MDi_L$$
$$i_C = C\frac{dv_a}{dt}$$
$$= -Ci_L(RD + LD^2),$$

and $$i_a = i_L + Ci_L(RD + LD^2),$$
$$i_aR_a = i_LR_a + CR_ai_L(RD + LD^2),$$

also $$i_aR_a = -i_L(R + DL) - \mu MDi_L$$

$$\therefore \{LCR_aD^2 + (CRR_a + L + \mu M)D + (R_a + R)\}i_L = 0$$

$$\left\{LD^2 + \left[R + \frac{1}{CR_a}(L + \mu M)\right]D + \frac{1}{C}\left(1 + \frac{R}{R_a}\right)\right\}i_L = 0$$

If $a = L$, $b = \left[R + \frac{1}{CR_a}(L + \mu M)\right]$, and $c = \frac{1}{C}\left(1 + \frac{R}{R_a}\right)$.

The auxiliary equation to this may be written :—

$$am^2 + bm + c = 0$$

and the solution of the differential equation is in the form :—

$$i_L = \epsilon^{mt}$$

where $m = -\frac{b}{2a} \pm \sqrt{\frac{b^2 - 4ac}{4a^2}}$.

The roots of m are real if

$$b^2 - 4ac > 0$$

i.e. $\left\{\left[R + \frac{1}{CR_a}(L+\mu M)\right]^2 - \frac{4L}{C}\left(1+\frac{R}{R_a}\right)\right\} > 0.$

This means that the circuit is aperiodic and is non-oscillatory.

The roots are imaginary if

$$b^2 - 4ac < 0$$

i.e. $\left\{\left[R + \frac{1}{CR_a}(L+\mu M)\right]^2 - \frac{4L}{C}\left(1+\frac{R}{R_a}\right)\right\} < 0,$

and the current i_L is expressed in the form :—

$$i_L = A\epsilon^{-b/2a \cdot t} \sin\left(\frac{4ac - b^2}{2a} \cdot t + B\right)$$

$$= A\epsilon^{-\alpha t} \sin(\omega t + \theta)$$

$$\omega = \frac{1}{2L}\sqrt{\frac{4L}{C}(1 + R/R_a) - \left[R + \frac{1}{CR_a}(L + \mu M)\right]^2} \quad \ldots \quad \ldots \quad 1$$

$$\alpha = \frac{1}{2L}\left[R + \frac{1}{CR_a}(L + \mu M)\right]$$

is the damping factor, and when positive the sinusoidal oscillations of i_L are damped, *i.e.*, when M is positive, or when

$$-M < \frac{1}{\mu}(L + CRR_a).$$

A shock on the circuit will produce oscillations of a frequency corresponding to ω, but they will be damped out.

When α is negative, however, we have the important case of sustained oscillations. Not only are the oscillations sustained, but they are increased due to the negative damping until the limits of the characteristic curve of the valve take effect.

When α is negative $\left\{R + \frac{1}{CR_a}(L+\mu M)\right\} < 0$, and hence M must be negative and numerically greater than $\frac{1}{\mu}(L + CRR_a)$.

Hence critical $M = -\frac{1}{\mu}(L + CRR_a)$.

Therefore the limit of oscillations occurs when

$$M = -\frac{1}{\mu}(L + CRR_a) \quad \ldots \quad 2$$

We therefore see that the frequency of oscillations produced is

$$f = \frac{1}{4\pi L}\sqrt{4L/C(1 + R/R_a) - \left[R + \frac{1}{CR_a}(L + \mu M)\right]^2} \quad \ldots \quad \ldots \quad 3$$

We must remember, however, that we have deduced this from initial circumstances, and it merely relates therefore to the critical conditions of oscillation without regard to subsequent events. For instance, we must bear in mind that directly the critical value of M is satisfied and the oscillations commence it is likely that the amplitude of oscillations will increase until the saturation part of the characteristic is reached. In all probability the immediate result is that the R_a has changed in value, so we can no longer apply our derived equations to the circuit, for initial conditions are now altered. All we can say is that if M corresponds exactly to the critical value $-\frac{1}{\mu}(L + CRR_a)$, then the circuit will just oscillate at

$$f = \frac{1}{2\pi}\sqrt{\frac{1 + R/R_a}{LC}},$$

neglecting grid current; but the slightest increase of M will alter conditions at once.

A slightly different method of treatment due to Prof. Fortescue is now given ; here grid current is considered (see Fig. 3*c*).

R_g is the resistance offered by the grid path of the valve to the flow of i_g.

$$Z_1 = R_1 + j\omega L_1 + R_g$$

$$Z_2 = Z_L + Z_C$$

$$Z_L = R + j\omega L$$

$$Z_C = \frac{1}{j\omega C}$$

Now $v_g = i_g R_g = R_g \cdot \frac{-j\omega M i_L}{Z_1}$

and $v_{AB} = -v_a = i_L Z_L - e_L + j\omega M i_g$

also $v_a = (i_L - i_a)Z_C$

i.e. $i_a = \frac{i_L Z_C - v_a}{Z_C}$

but $i_a = Gv_g + \frac{v_a}{R_a}$.

Combining these equations and eliminating i_a, v_a, v_g, we get i_L in terms of e_L, from which follows the effective impedance of the oscillatory circuit: *i.e.*, (e_L/i_L)

$$i_L\left(Z_2 + \frac{\omega^2 M^2}{Z_1} + \frac{Z_C}{Z_1}\cdot GR_g j\omega M + \frac{Z_C Z_L}{R_a} + \frac{Z_C}{Z_1}\cdot\frac{\omega^2 M^2}{R_a}\right) = e_L\left(1 + \frac{Z_C}{R_a}\right)$$

For oscillations we must have "effective Z" $= 0$, and if we equate the vertical component (j terms) of $Z_{eff.}$ to zero, we get :—

$$\omega L - \frac{1}{\omega C} - \frac{\omega^2 M^2 \omega L_1}{[(R_1+R_g)^2 + \omega^2 L_1^2]} - \frac{\omega M L_1 G R_g}{[(R_1+R_g)^2 + \omega^2 L_1^2]C} - \frac{R}{\omega R_a C} - \frac{\omega^2 M^2 (R_1+R_g)}{\omega R_a C[(R_1+R_g)^2 + \omega^2 L_1^2]} = 0$$

i.e.,

$$\omega^4 \cdot \frac{M^2 L_1 C}{[(R_1+R_g)^2 + \omega^2 L_1^2]} - \omega^2\left\{LC - \frac{M L_1 G R_g + \dfrac{M^2(R_1+R_g)}{R_a}}{[(R_1+R_g)^2 + \omega^2 L_1^2]}\right\} + \left(1 + \frac{R}{R_a}\right) = 0$$

(say) $$a\omega^4 - \beta\omega^2 + \gamma = 0$$

then $$\omega^2 = \beta/2a \pm \beta/2a\sqrt{1 - \frac{4a\gamma}{\beta^2}}.$$

LC is the important term, all the others being small compared to it, hence $\frac{4a\gamma}{\beta^2}$ is small, and we may say approximately

$$\omega^2 = \beta/2a\left\{1 \pm \left(1 - \frac{2a\gamma}{\beta^2}\right)\right\} = \frac{\gamma}{\beta} \text{ or } \frac{\beta}{a} \text{ approx.}$$

γ/β will give the value which is nearly equal to ω_0, where $\omega_0 = 2\pi f_0$, f_0 being the "LC" frequency.

$$\omega^2 = \frac{1 + R/R_a}{\left\{LC - \dfrac{M L_1 G R_g + M^2\left(\dfrac{R_1+R_g}{R_a}\right)}{[(R_1+R_g)^2 + \omega^2 L_1^2]}\right\}} \quad \ldots 4$$

This equation indicates to what extent grid current modifies the oscillator frequency. If $R_g = \infty$, then there is no grid current and we have as before

$$\omega^2 = \frac{1 + R/R_a}{LC} \quad \ldots \quad \ldots \quad \ldots 5$$

It is difficult to estimate the value of R_g in the present case, but if we put it at 10^5 ohms, then $R_1 = 226$ ohms (see next sub-section) and $\omega L_1 = 2\pi \,.\, 640 \,.\, 0.142 = 562$ ohms are both negligible compared to R_g and our equation is reduced to :—

$$\omega^2 = \frac{1 + R/R_a}{\left\{LC - \dfrac{M^2}{R_a R_g}\left(1 + \mu\dfrac{L_1}{M}\right)\right\}} \quad \ldots 6$$

$$f^2 = \frac{1 + R/R_a}{2\pi LC\left\{1 - \dfrac{M^2}{LCR_a R_g} - \dfrac{\mu}{R_a}\cdot\dfrac{ML_1}{R_g}\cdot\dfrac{1}{LC}\right\}}$$

$$f^2 = f_0^2\,\frac{1 + R/R_a}{\left\{1 - \dfrac{M^2}{LCR_a R_g} - \dfrac{\mu}{R_a}\cdot\dfrac{ML_1}{R_g}\cdot\dfrac{1}{LC}\right\}} \quad \ldots 7$$

Upon equating the horizontal terms :—

$$R + \frac{\omega^2 M^2}{R_g}\left(1 - \frac{L_1}{R_a R_g C}\right) + \frac{\mu M}{CR_a} + \frac{L}{CR_a} = 0.$$

By neglecting the small terms this reduces to :

$$\frac{M^2 R_a}{LR_g} + \mu M + (CRR_a + L) = 0.$$

When grid current is negligible, R_g is ∞ and we have the usual critical

$$M = -\frac{1}{\mu}(CRR_a + L).$$

For small grid currents we may write

$$M = -\frac{1}{\mu}\left(CRR_a + L + \frac{M^2 R_a}{LR_g}\right) \quad \ldots 8$$

(c) *Procedure.*

The inductance of the anode coil (also the grid coil) was first measured using a Campbell Inductometer in a Maxwell Bridge arrangement. The mean of several readings gave

Anode Coil $\begin{cases} L = 484.5 \text{ millihenrys.} \\ R = 19 \text{ ohms.} \end{cases}$

Grid Coil $\begin{cases} L_1 = 141.9 \text{ millihenrys.} \\ R_1 = 226 \text{ ohms.} \end{cases}$

The mutual inductance M between the grid and anode coil was next determined for various positions of the grid coil, again

using the Campbell Inductometer as a standard. The calibration curve is given in Fig. 4.

When the apparatus had been set up, various trial tests were made obtaining beats between the oscillator frequency and the tuning fork harmonics. The beats were easily distinguishable and the whole arrangement seemed quite satisfactory, as there was no tendency for the notes to lock. At first only 60 volts H.T. and $1\frac{1}{2}$ volts grid bias were used, but these were altered later to more suitable values.

Oscillator Frequency.—The condensers C were arranged to give a frequency of approximately 256 cycles to beat with the second harmonic of the fork note. The oscillator, however, did not seem to oscillate very easily at this frequency. Similarly at 384 cycles (the 3rd harmonic of the fork note), so the frequency was increased to about 640 cycles to beat against the 5th harmonic of the fork note. Touching various parts of the oscillator circuit with the hand was found to alter beats considerably, so the circuit was earthed. Close proximity (without touching) of the hand or body to the circuit made no difference at all. Inserting a milliammeter into the anode circuit made a slight difference, so it was decided to include everything in the circuit that would be necessary for all subsequent tests, so that the conditions would not be changed. Therefore, the dial boxes, filament resistance, and meters were all connected up. The effect of varying grid coupling was found to be considerable.

"LC" Frequency. Having decided upon the oscillator frequency, about 640 cycles, we must settle upon an exact value for the capacity C to give us the theoretical

$$f_0 = \frac{1}{2\pi\sqrt{LC}}.$$

We want f_0 to be fixed so f_0 will be made equal to $5 \times 127.741_{15} \ldots$ cycles, *i.e.*, $638.706 \ldots$ cycles, which is the 5th harmonic of the maintained tuning fork frequency.

$$C = \frac{10^3}{4\pi^2(638.706)^2 \,.\, 484.5} \text{ farads.}$$
$$= 128{,}165\ldots\ \mu\mu\text{fds.}$$
$$= 116.51 \ldots \text{ jars.}$$

Hence using all the coils of L and a capacity C of 116.51 jars the theoretical "LC" frequency is $f_0 = 638.706$ cycles.

Owing to various practical conditions, however, the frequency of the oscillator will not equal f_0, but some frequency f. f will beat against f_0 the 5th harmonic of the tuning fork, and our frequency departure is given direct by the number of beats.

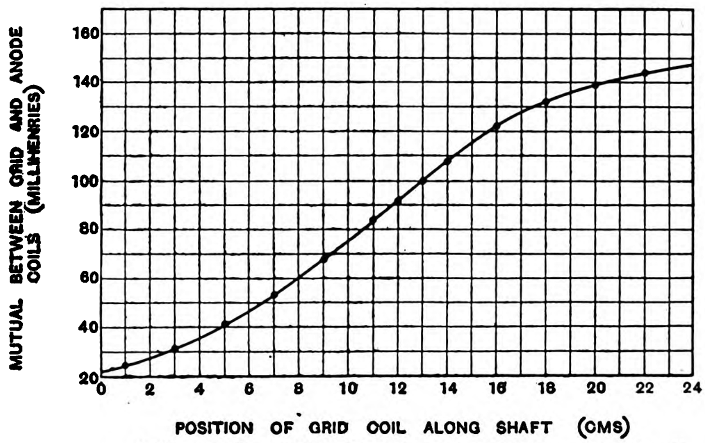

Fig. 4.—*Grid coupling calibration curve for position of grid coil.*

(To be concluded.)

Potential Difference and Electromotive Force.

By E. A. Biedermann, B.Sc., A.M.I.E.E.

Introduction.

THE question of the exact meanings to be assigned to the terms "potential difference" and "E.M.F." has been recently discussed in this journal in editorials by Prof. Howe* and in an article by Mr. R. M. Wilmotte.† The subject is one of more than academic interest since, as Mr. Wilmotte points out, the definition of potential difference is involved in a number of other definitions of fundamental importance, such as those of impedance, capacity, self-inductance, etc.

Mr. Wilmotte in his very interesting paper proposed certain definitions for the above terms, and the purpose of this article is to discuss these suggested definitions with a view to showing that on close examination they cannot really be said to satisfy the conditions which Mr. Wilmotte has rightly pointed out must be satisfied by any such definitions, namely, that they shall not only be mathematically rigorous, but also be in accord with generally accepted ideas as to the meanings of the terms.

In the case of an electrostatic system there is no difficulty, because no ambiguity, in defining the potential at any point as the work done in bringing a unit positive charge from an infinite distance to the point, since this work is quite independent of the particular path chosen. Mr. Wilmotte therefore suggests that in the general case of any electrical system it would appear simplest to define potential difference as the work done on the unit charge in bringing it from an infinite distance by a path so selected that no E.M.F. due to electromagnetic induction acts along it. Actually his method of procedure is not directed to finding such a path, but consists in an analytical separation of the different force components which together constitute the resultant electric intensity. Probably this latter method is really the only practicable one, since it is difficult to see how a specification could be given of a path along which no E.M.F. is induced which would be of general applicability.

Effect of Finite Velocity of Transmission.

Mr. Wilmotte analyses the electric intensity as the resultant of two electric force components, one derived from the scalar potential and the other from the vector potential of classical electromagnetic theory—the so-called *retarded* potentials.

The scalar potential is given by the expression

$$\phi = \Sigma \frac{[q]}{r}$$

and the rectangular components of the vector potential by

$$A_x = \frac{1}{c^2}\Sigma\frac{[i_x]}{r},\ A_y = \frac{1}{c^2}\Sigma\frac{[i_y]}{r},\ A_z = \frac{1}{c^2}\Sigma\frac{[i_z]}{r},$$

q denoting an element of charge, i_x, i_y, i_z conduction current components, and r the distance from the element of charge, or current, to any point P at which it is desired to evaluate the potentials.

The symbols denoting the charge elements and current components have been enclosed in square brackets, in accordance with a convenient practice usually adopted in dealing with these potentials, to denote that the values of these quantities are not those existing at the instant t at which it is required to evaluate the potentials, but at instants $t_0 = \left(t - \frac{r}{c}\right)$, in consequence of the fact that all electromagnetic disturbances are propagated with a constant velocity c whose magnitude depends on the dielectric constant and permeability of the medium. Hence the term *retarded* potentials.

Mr. Wilmotte draws attention to this in a footnote in which he states that it may *sometimes* be necessary to take this effect into account at *high frequencies*. The italics are mine, because I believe that, in seeking to frame definitions of potential difference and E.M.F. which shall be of general applicability, it is absolutely essential

* March and April, 1928.

† Some Fundamental Definitions, by Raymond M. Wilmotte, B.A., A.M.I.E.E., November, 1928.

to take this factor into account. The omission to do so really obscures the whole subject. One immediate consequence of this omission in Mr. Wilmotte's paper is that he is led in the first place, when considering an electrical system as a whole, to identify "potential," as ordinarily understood, with the scalar potential ϕ, and to refer to the force derived from it as the *electrostatic* force. On taking into account, however, this factor of the finite velocity of transmission it will be found that, whenever the system involves a varying current, the force derived from the scalar potential is not merely an electrostatic force, but includes also a component which is essentially an *electromagnetic* force, just as much so as the force derived from the vector potential. As a consequence, I think it must be admitted that we cannot identify "potential" as commonly understood, with the scalar potential without departing radically from accepted ideas as to what is meant by potential difference.

Electric Force Component Derived from the Scalar Potential.

To make this clear it will be necessary to make use of a little mathematics. The component, along any element of path ds at the point P, of the force derived from the scalar potential is given by

$$E_s = -\frac{d\phi}{ds} = -\frac{d}{ds}\Sigma\frac{[q]}{r} = -\Sigma\frac{d}{ds}\left(\frac{[q]}{r}\right)$$
$$= -\Sigma[q]\frac{d}{ds}\left(\frac{1}{r}\right) - \Sigma\frac{1}{r}\frac{d[q]}{ds}$$

Now, in the case of an electrostatic system $\frac{d[q]}{ds}$ vanishes, because $[q]$ is not varying with time. At first sight it might be thought that the same is true when the system involves varying currents, and therefore varying charges, since we are only differentiating with regard to space at a given instant. Actually $\frac{d[q]}{ds}$ then has a finite value. If P_1, P_2 denote the extremities of a small element of path δs at the point P, then $\frac{d[q]}{ds}$ denotes the limit of $\{[q_2] - [q_1]\}/\delta s$ and there is a change in the value of $[q]$ due to the fact that $[q_1]$ is the value of $[q]$ at the instant $t_1 = \left(t - \frac{r_1}{c}\right)$, while $[q_2]$ denotes the value of $[q]$ at the instant $t_2 = \left(t - \frac{r_2}{c}\right)$, where r_1, r_2 denote respectively the distances from the element of charge to the points P_1, P_2. If, then, $[q]$ is varying at the rate $\left[\frac{dq}{dt}\right]$, there is a change in the value of $[q]$ of amount

$$\left[\frac{dq}{dt}\right](t_2 - t_1) = -\left[\frac{dq}{dt}\right]\left(\frac{r_2}{c} - \frac{r_1}{c}\right)$$
$$= -\left[\frac{dq}{dt}\right]\frac{\delta r}{c}$$

where δr denotes the difference in the values of r for the points P_1, P_2, assuming the position of $[q]$ to remain unaltered. Hence, in the limit

$$\frac{d[q]}{ds} = -\frac{1}{c}\left[\frac{dq}{dt}\right]\frac{dr}{ds}.$$

Substituting this value of $\frac{d[q]}{ds}$ in the expression for E_s above, and writing $\frac{1}{r^2}\frac{dr}{ds}$ for $-\frac{d}{ds}\left(\frac{1}{r}\right)$, we obtain

$$E_s = \Sigma\frac{[q]}{r^2}\frac{dr}{ds} + \Sigma\frac{1}{cr}\left[\frac{dq}{dt}\right]\frac{dr}{ds}.$$

Obviously the part $\Sigma\frac{[q]}{r^2}\frac{dr}{ds}$ corresponds closely to a true electrostatic force, though it should be noted that it is not quite the same thing as the electrostatic force which would exist if the charge distribution were imagined to become suddenly fixed, because the distribution represented by $\Sigma[q]$ is not a distribution existing at any *one* instant, the values of $[q]$ being those of the charges each taken at a different instant depending on the distances of the individual charges from the point P. Still this part of the electric intensity does depend on every element of charge at its appropriate instant, and on its distance, in exactly the same way as a true electrostatic force, so that it is, I think, quite legitimate, and certainly convenient, to refer to it as the electrostatic component of the electric intensity. If we wish to be very accurate we might term it the *retarded* electrostatic force.

The other part of the force E_s derived from the scalar potential, namely, the part whose component parallel to ds is represented by $\Sigma \frac{1}{cr}\left[\frac{dq}{dt}\right]\frac{dr}{ds}$ is essentially a force of an electromagnetic nature, because varying charges on a system are necessarily dependent on the existence of varying currents, as Mr. Wilmotte has emphasised in his article. In fact, as is well known, if q denote the charge on an element of circuit ds', $\left[\frac{dq}{dt}\right] = -\left[\frac{di}{ds'}\right]$, so that the above force component may be written

$$-\Sigma \frac{1}{cr}\left[\frac{di}{ds'}\right]\frac{dr}{ds}.$$

It is, of course, quite true that the line integral of the whole force E_s derived from the scalar potential vanishes when integrated round any closed path, and a definition of "potential" as being the same thing as the scalar potential ϕ therefore satisfies the condition that the work done in bringing a unit charge to the point against the whole force derived from that potential shall be independent of the path followed. On the other hand, I submit, it does not satisfy the other requirement that the definition shall be in accordance with what is generally understood by the term "potential." I doubt if forces of an essentially electromagnetic nature are ever associated with potential difference. Such forces are invariably thought of as E.M.F.'s.

Comparison of Electromagnetic Forces Derived from Scalar and Vector Potentials.

It may be thought that in practice the electromagnetic part of the force derived from the scalar potential will in general be negligible, and in the case of *closed* circuits this may well be the case, except under the special conditions referred to by Mr. Wilmotte in his footnote, but in the case of *open* circuits this is not so. It is true that at points not very distant from an open circuit this force may be negligibly small compared with the *electrostatic* force, but the point I wish particularly to emphasise is that in such cases, with a non-magnetic medium, it is always in some directions comparable with the electromagnetic force derived from the *vector* potential, *no matter how low the frequency*.

That this must be so is easily appreciated if we think for a moment of that part of the resultant electric intensity which constitutes what is usually referred to as the *radiation* field, the only part which is appreciable at large distances from the radiating system. It is well known that the contribution of each current element of a circuit to this radiation field is an element of force proportional to the rate of change of the current, varying inversely as the distance from the element of circuit, and that it is *perpendicular to the radius vector from the element of circuit to the point considered.*

Now, it is obvious that the radiation component derived from the *vector* potential is *parallel* to the current element. There must be, therefore, some corresponding *radial* component of electric intensity produced by the same current element. This radial component is derived from the *scalar* potential. At points in the line through the current element the two force components are actually equal but oppositely directed, so that the contribution of the current element to the radiation intensity is nil.

It is not at first sight very clear how a force component proportional to $\left[\frac{di}{dt}\right]$ can be accounted for by the electromagnetic force $-\frac{1}{cr}\left[\frac{di}{ds'}\right]$ which we have seen is derived from the scalar potential due to the charge on an element of circuit, but it must be remembered once again that the current can only vary from point to point of the circuit in virtue of the fact that it is also varying with time, and consequently $\left[\frac{di}{ds'}\right]$ must essentially depend on $\left[\frac{di}{dt}\right]$. It may be shown, in fact, that the electromagnetic force derived from the scalar potential due to the whole circuit includes a part which is the resultant of contributions from each element of circuit of a radial component proportional to $\left[\frac{di}{dt}\right]$ and varying with distance and direction in exactly the required manner.

Thus the scalar potential due to an open circuit gives rise, in a non-magnetic medium,

to an electromagnetic force which is in general comparable with that which is derived from the vector potential. In view of this is it not rather an arbitrary procedure to associate the former force with potential, or potential difference, in its commonly understood sense?

Mr. Wilmotte, I think, does not really contemplate this, but, by omitting to take account of the fact that the scalar potential is a *retarded* potential, he has not brought to light the fact that other forces than electrostatic forces are derived from the scalar potential.

System Consisting of Transmitting and Receiving Antennæ.

It is really on account of this omission that, having tentatively identified "potential" with the scalar potential when considering a system as a whole, he is at once confronted with the difficulty that the commonly accepted meaning of the E.M.F. induced in a distant antenna includes forces represented by the "$\frac{d\phi}{dx}$ terms." Of course it does, because these terms represent forces which are partly *electromagnetic* and therefore properly to be regarded as giving rise to an E.M.F. rather than a potential difference. As a matter of fact, the purely electrostatic part of the forces represented by the "$\frac{d\phi}{dx}$ terms" in the case of a distant antenna may be considered as being for all practical purposes negligible, for the simple reason that the resultant charge on the whole of the transmitting system is nil, and that the dimensions of the system are very small compared with the assumed large distance of the receiving antenna. For all practical purposes, therefore, we could quite satisfactorily define the E.M.F. induced in the distant antenna as the line integral of all the *electromagnetic* forces induced in it.

When, however, the two antennæ are brought close together, as Mr. Wilmotte proceeds to consider, the electrostatic forces are no longer negligible and may exceed the electromagnetic forces. Nevertheless, there is still no reason, as far as I can see, why the electrostatic forces should be regarded as contributing to the E.M.F. induced in the receiving antenna.

Mr. Wilmotte says that in these circumstances the reaction of the one antenna on the other is commonly called the mutual induction, but I think this term is usually taken to denote only the mutual *electromagnetic* induction. The whole reaction of one antenna on the other comprises the effects of *electrostatic* induction in addition to those of mutual induction, and it is precisely when the *electrostatic* forces become appreciable that electrostatic induction occurs, and potential differences, not E.M.F.'s, are produced thereby. This, I think, is the generally accepted view.

Mr. Wilmotte's Proposed Definitions of Potential Difference.

The position with regard to Mr. Wilmotte's suggested definitions of potential difference appears to be this. His first definition, when considering an electrical system as a whole, appears at first sight to accord with generally accepted ideas as to the meaning of the term only because it has not been treated rigorously. When considering the E.M.F. induced in a distant antenna, however, the definition *is*, in effect, rigorously treated, for it is only by so treating it that the E.M.F. would be found to involve the "$\frac{d\phi}{dx}$ terms" appreciably, and then it is at once seen that the definition is not in accordance with generally accepted ideas. He is therefore forced to revise his definition of potential difference and take it to mean the effect arising from the charge distribution only on the part of the system considered, *i.e.*, the distant receiving antenna in that particular instance. He even goes so far as to suggest that this revised definition can be applied to any selected part of a single circuit. Consider for a moment what this leads to. A definition, to be valid, must be so under all circumstances, and it must therefore apply to a circuit carrying a steady current. Mr. Wilmotte's revised definition then asserts that the potential difference between the extreme points A and C of any selected section ABC of the circuit is that arising from the charge distribution on the section ABC alone. But the generally accepted meaning of the potential difference between A and C in such circumstances is unquestionably a quantity equal to the

product of the resistance of the section ABC and the current flowing through its assuming, of course, that no sources of E.M.F. are connected in that section. If this is equal to the potential difference arising from the charges on ABC alone, then the effect on ABC of the charge distribution on the remainder of the circuit must be nil, which cannot possibly in general be the case. In this simple case it is quite certain that the accepted meaning of the potential difference between A and C is that arising from the charge distribution on the *whole* circuit. It is certainly not considered that the effect on ABC of the charge distribution on the remainder of the circuit is to be regarded as an E.M.F., as Mr. Wilmotte's revised definition requires us to regard it. It appears very unlikely, therefore, that this particular definition will receive general acceptance. One is forced to the conclusion, therefore, that any attempt to generalise the meaning of potential difference by associating potential, as commonly understood, with the scalar potential of electromagnetic theory must fail, because it will not satisfy the second condition enunciated by Mr. Wilmotte that any definition must submit to: the generally accepted meaning of the term.

Possible Alternative Definitions.

As a possible alternative may I suggest that the term potential difference be generalised to mean always the line integral of only that force which depends on the charge distribution, the force represented by $\Sigma \frac{[q]}{r^2} \frac{dr}{ds}$, which corresponds very closely to a true electrostatic force and forms a part in all circumstances of the force derived from the scalar potential.

It is easily shown that the line integral of this particular force in all cases vanishes round a closed path and this definition therefore meets the requirement that the work done on a unit charge in moving it between two points against this force shall be independent of the particular path followed. The line integral of all other forces, whether derived from the scalar or vector potential, would then define the E.M.F., and it is to be noted that these other forces are all electromagnetic forces, depending directly on the distribution of *currents* not on the distribution of *charges*.

After all, is it not more satisfactory to base our definitions of P.D. and E.M.F. on a classification of forces, which have an actual physical existence, rather than on a classification of potentials, which can hardly be regarded as more than mathematical conceptions in spite of the great help they afford in mathematical investigations of electrical phenomena ?

The only disadvantage that would appear to arise from such definitions is that we cannot express the potential in the general case in a convenient mathematical form, but only as the line integral from an infinite distance of the force $\Sigma \frac{[q]}{r^2} \frac{dr}{ds}$.

The Marconi Company and Licensees.

Under the term of the proposed new Licence Agreement between the Marconi Company and manufacturers of broadcast receiving apparatus which has been negotiated on behalf of licensees of the Marconi Company by the Radio Manufacturers' Association, the following main heads indicate the general terms under which the new licence will be issued. The A.2. Licence referred to below is, of course, the present general Licence Agreement issued by the Marconi Company.

(*a*) A new Agreement dating from 28th August, 1928, to 28th August, 1933, covering patented and non-patented goods for the field of broadcast reception.

(*b*) The new Licence shall cover the existing patents set out in the schedule to the A.2. Licence, the Eliminator Patent (148,129 at present the subject of their D Licence), all other present and future patents controlled by the Marconi Co. and their Associates the Gramophone Co. in the field as defined in Clause (*a*).

(*c*) Licensees shall give to the Marconi Co. (and to its Associate Company the H.M.V.) the free use of any patents they may possess dealing with the field as defined in Clause (*a*). In respect of the eliminator patent the actual royalty in respect of this patent shall be 5/- per apparatus when embodied in a receiving set. The charge when the apparatus is not so included shall be 6 per cent. of the retail list price.

(*d*) The Radio Manufacturers' Association will call the attention of the Marconi Company to any cases of infringement of the patents, with a request that such infringers shall be prosecuted. Should the Marconi Company not be prepared to undertake such prosecution, the question of the prosecution shall be referred to the arbitration of the President of the Law Society whose decision shall be binding on both sides.

(*e*) The royalty to be 5/- per valve-holder, the term valve-holder to have the meaning attached to it in the A.2. Licence.

The Triode Valve Equivalent Network.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

1. Introduction.—Assumptions, Scope and Object of the Paper.

THE analysis of the valve equivalent network as usually presented is not in the form best adapted either for numerical application or for the deduction of the general character of the variation of the important quantities of the network with the load in the anode circuit. Even the simplest triode network contains so many possible variables that unless these are grouped in such a way as to give due prominence to the important terms the resulting formulæ are so complicated that it is difficult to " see the wood for the trees."

The following presentation of the subject is an attempt to reduce the formulæ to their simplest form. It is based upon the assumptions made by Miller in his original treatise,* with the complementary modifications introduced by Hartshorn† (i.e., the inclusion of a conductance term in the admittances of the inter-electrode condensers). These assumptions have already received a sufficient degree of experimental confirmation to establish their utility as the basis of design and as a guide to further experimental work.

The analysis is confined to the network equivalent to a single valve and to the study of:

(*a*) The input admittance.

(*b*) The voltage amplification.

The means of extending the analysis to multi-valve networks in which all stray couplings are eliminated by screening and other suitable precautions, are implicit in the analysis and are pointed out in the course of it. For convenience the total range of frequency is divided into (*a*) audible frequencies, (*b*) radio frequencies, the line of division being in the neighbourhood of 20 kilocycles per second.

* Miller: *Bull. Bur. Stand.*, Vol. 15, p. 367 (1919).

† *Proc. Phys. Soc.*, Vol. 39, Part 2, 1927.

It is hoped that the paper will serve the following purposes:

(*a*) Elucidation of experimental data already obtained.

(*b*) Indication of useful lines of future investigation.

(*c*) Guidance in design, particularly in relation to very high radio frequencies.

2. The Network and Notation.

The network considered is illustrated in Fig. 1. It represents a valve having a voltage factor μ and internal A.C. resistance R_a. The grid-filament, grid-anode and anode-filament capacities are represented by the small condensers C_1, C_2 and C_3.

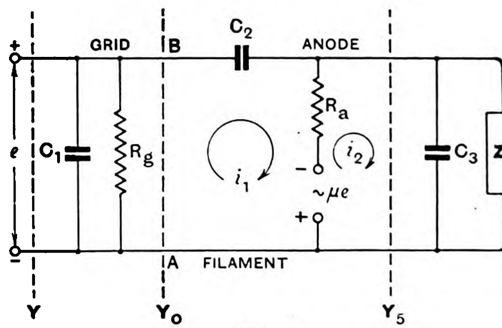

Fig. 1.

The analysis relates throughout to simple harmonic currents and potential differences of frequency $\omega/2\pi$. These are represented in vector form, the circuit characteristics being in consequence " vector operators," or two-dimensional numbers. Any impedance is thus expressible as the two-dimensional number $R + jX$, without assumption as to the form of the numbers R and X, where j obeys the same formal rules as $\sqrt{-1}$. As a single letter it is written $\mathbf{Z}$, the magnitude being $Z\ (= \sqrt{R^2 + X^2})$. The corresponding admittance is $\mathbf{Y} = G + jS$, i.e.,

$$\frac{1}{\mathbf{Z}} = \frac{1}{R + jX} = \mathbf{Y} = G + jS$$

Thus the admittances of the inter-electrode capacities are:

$$\mathbf{Y}_1 = G_1 + jS_1 = G_1 + j\omega C_1, \text{ etc., etc.}$$

The anode circuit load is $\mathbf{Z}_4$. For completeness a resistance R_g ($= 1/G_g$) is introduced to represent possible grid-filament conductivity (e.g., as in cases involving grid-circuit rectification).

3. A Simplification of the Network.

From the point of view of voltage amplification the resultant load in the anode circuit is the actual load $\mathbf{Z}_4$ (admittance $\mathbf{Y}_4$) shunted by the anode-filament capacity of admittance $\mathbf{Y}_3$. It will, therefore, be convenient to combine these two elements in a single symbol $\mathbf{Y}_5$, i.e.,

$$\mathbf{Y}_5 = \mathbf{Y}_4 + \mathbf{Y}_3$$

4. Extension to a Multi-valve Network.

If the valve considered is followed by another, the input admittance of the following valve, modified in some calculable manner by the coupling elements, will appear as a further shunt path to the anode circuit load. Writing $\mathbf{Y}_x$ for this additional admittance, the resultant anode circuit load is now

$$\mathbf{Y}_5 = \mathbf{Y}_4 + \mathbf{Y}_3 + \mathbf{Y}_x$$

In all that follows the symbol $\mathbf{Y}_5$ will be taken to have the above inclusive significance.

5. Elimination of Known Terms from the Input admittance.

The total input admittance $\mathbf{Y}$ is given by $\mathbf{Y} = \mathbf{Y}_1 + G_g + \mathbf{Y}_0$, where $\mathbf{Y}_0$ is the admittance of the remainder of the network (to the right of the dotted line AB in Fig. 1). Of these the only unknown term is $\mathbf{Y}_0$, the other terms being determinable constants for the valve, not affected by $\mathbf{Y}_5$. This term $\mathbf{Y}_0$ is therefore the one that will be investigated, the total input admittance being obtained merely by including the simple additive terms $\mathbf{Y}_1$ and G_g.

The above simplifications reduce the equations to two only. It may, however, be as well to point out that an assumption is involved at this point. It is assumed that the input admittance of the valve is independent of the manner in which the potential difference e is produced between the grid and the filament, i.e., that it is quite independent of the input circuit. The usual network representation necessarily involves this conclusion. The practical aspect of the assumption is that the input circuit has no external coupling to the output circuit, a condition which can easily be obtained by screening.

6. The Circuit Equations.

The currents $\mathbf{i}_1$ and $\mathbf{i}_2$ are given by the equations

$$\mathbf{i}_1\left(\frac{1}{\mathbf{Y}_2} + \frac{1}{G_a}\right) - \frac{\mathbf{i}_2}{G_a} = (\mu + 1)\mathbf{e} \quad \ldots \quad (1)$$

$$\mathbf{i}_2\left(\frac{1}{\mathbf{Y}_5} + \frac{1}{G_a}\right) - \frac{\mathbf{i}_1}{G_a} = -\mu\mathbf{e} \quad \ldots \quad \ldots \quad (2)$$

the solutions of which are

$$\mathbf{i}_1 = \left\{\frac{(\mu + 1)G_a + \mathbf{Y}_5}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2}\right\}\mathbf{Y}_2\mathbf{e} \quad \ldots \quad (3)$$

$$\mathbf{i}_2 = \left\{\frac{\mathbf{Y}_2 - \mu G_a}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2}\right\}\mathbf{Y}_5\mathbf{e} \quad \ldots \quad (4)$$

Thus the input admittance term $\mathbf{Y}_0$, i.e., $\mathbf{i}_1/\mathbf{e}$, is

$$\mathbf{Y}_0 = \left\{\frac{(\mu + 1)G_a + \mathbf{Y}_5}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2}\right\}\mathbf{Y}_2 \quad \ldots \quad (5)$$

and the voltage amplification $\mathbf{M} = \frac{\mathbf{v}}{\mathbf{e}} = \frac{\mathbf{i}_2/\mathbf{Y}_5}{\mathbf{e}}$

is

$$\mathbf{M} = \frac{\mathbf{Y}_2 - \mu G_a}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2} \quad \ldots \quad (6)$$

7. Representation for Analytical Purposes.

A great gain in generality is obtained by expressing the above formulæ in terms of a new variable

$$\mathbf{r} = a + jb = \frac{G_a}{G_a + \mathbf{Y}_5} = \frac{\mathbf{Z}_5}{\mathbf{Z}_5 + R_a}$$

The justification for this substitution and its significance are discussed below. This quantity will be referred to as the "load factor."

An additional convenient group symbol is

$$p = \frac{\mathbf{Y}_2}{G_a} = \mathbf{Y}_2 R_a$$

It will appear that this ratio is more important than the individual terms $\mathbf{Y}_2$ and G_a.

Making these substitutions, the Equations (5) and (6) become

$$\mathbf{Y}_0 = \left(\frac{1 + \mu\mathbf{r}}{1 + p\mathbf{r}}\right)\mathbf{Y}_2 \quad \ldots \quad (7)$$

$$\mathbf{M} = -\left(\frac{1 - p/\mu}{1 + p\mathbf{r}}\right)\mu\mathbf{r} \quad \ldots \quad (8)$$

8. The Variable r.

The principal reason for the use of the load factor $\mathbf{r}$ is that this quantity is the real variable of the problem. It is this ratio that matters, rather than the individual quantities $\mathbf{Z}_5$ and R_a. It has the further advantage of restricted variation of a comparatively simple character.

Suppose first that $\mathbf{Z}_5$ is a pure resistance, of magnitude R_5. Then

$$\mathbf{r} = \frac{R_5}{R_a + R_5}$$

and is wholly "real." Further, as R_5 is varied from 0 to ∞, $\mathbf{r}$ varies from 0 to 1, so that every possible value of R_5 is included in the range 0 to 1 of $\mathbf{r}$.

Now suppose $\mathbf{Z}_5$ to be a pure reactance, jX_5, then

$$\mathbf{r} = \frac{jX_5}{R_a + jX_5}$$

$$= \tfrac{1}{2}\left\{1 - \frac{R_a - jX_5}{R_a + jX_5}\right\}$$

Now whatever the magnitude of X_5, the

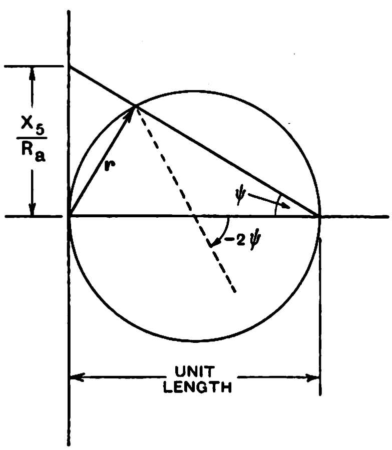

Fig. 2.

fraction inside the bracket is of magnitude 1 and represents a pure rotation. In fact

$$\mathbf{r} = \tfrac{1}{2}\{1 - \epsilon^{-2j\psi}\}$$

where $\tan\psi = X_5/Ra$.

As X_5 varies from $-\infty$ to $+\infty$, 2ψ varies from $-\pi$ to π, and the end of $\mathbf{r}$ simply moves round a circle of unit diameter as shown in Fig. 2. Thus for any pure reactance load, whether positive or negative (inductive or capacitative), $\mathbf{r}$ will terminate somewhere on the diameter of the circle shown in Fig. 2. For pure resistance loads, $\mathbf{r}$ will be wholly "real" and will terminate somewhere on the diameter of this circle. For any load whatever (excluding the special case of negative resistance components in the load) $\mathbf{r}$ must terminate somewhere on or inside the limiting circle. (Further circular loci for $\mathbf{r}$ are discussed in Appendix I.)

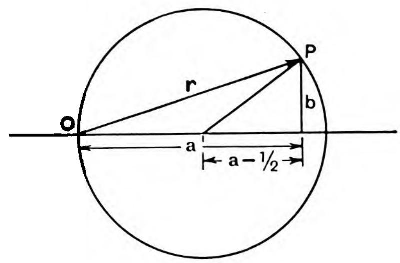

Fig. 3.

This leads to a simple means of making a complete survey of the possible variation of the input impedance and the voltage magnification of a valve. For points on the circumference of the limiting circle (i.e., for pure reactance loads)

$$\mathbf{r} = a + jb$$

and also $(a - 1/2)^2 + b^2 = 1/4$ (see Fig. 3)
i.e., $r^2 = a^2 + b^2 = a$ or $b = \pm\sqrt{a - a^2}$ (9)

Thus for a complete survey of the variation for the important case of pure reactive loads it is only necessary to calculate for convenient points on the diameter of the circle. Such points are

(*a*)	0	.1	.2	.3	.4	.5
(*b*)	0	$\pm$ .3	$\pm$ .4	$\pm$ .46	$\pm$ .49	$\pm$ .5
(*a*)	.6	.7	.8	.9	1	
(*b*)	$\pm$ .49	$\pm$ .46	$\pm$ .4	$\pm$ .3	0	

to convert back to actual reactance values if desired we have

$$\frac{X_5}{R_a} = \frac{b}{1 - a}$$

or alternatively the graphical construction of Fig. 2.

For pure resistance loads it is only necessary to calculate for the points $b = 0$

$a = .1, .2, .3$, etc., etc., with the reversion, if desired

$$\frac{R_5}{R_a} = \frac{a}{1 - a}$$

The more general case for any value of $\mathbf{r}$ whatever lying within the circle is considered in the Appendix.

The following general deductions with regard to the variation of the load factor $\mathbf{r}$ should be noted. Putting

$$\mathbf{r} = a + jb \; (r = \sqrt{a^2 + b^2})$$

(i) The limits of a are 0 and 1; of $b \pm \frac{1}{2}$; of $\mathbf{r}$, 0 and 1.

(ii) The limiting values of b correspond to finite values of the load ($Z_5 = |X_5| = R_a$). The limiting values of a and $\mathbf{r}$ will never be reached in practice, except by some special artifice, since they correspond to an infinite value for Z_5 (resistive or reactive).

(iii) Positive values of b correspond to positive values of X_5 (i.e., inductive loads), negative values of b to capacitative loads.

9. Deductions from the Network Formulæ at Audible Frequencies.

The formulæ are re-stated here for convenience

$$\mathbf{Y}_0 = \frac{1 + \mu\mathbf{r}}{1 + p\mathbf{r}} \mathbf{Y}_2 \qquad \ldots \quad (7)$$

$$\mathbf{M} = -\frac{1 - p/\mu}{1 + p\mathbf{r}} \mu\mathbf{r} \qquad \ldots \quad (8)$$

where $\quad p = \mathbf{Y}_2 R_a$

These will be considered in relation to a typical valve having the characteristics

$$R_a = 3 \times 10^4$$
$$\mu = 10$$
$$C_2 = 5 \times 10^{-12}$$
$$G_2/\omega C_2 = 0.1$$

At audible frequencies p is very small. Thus at

$$f = 10{,}000$$
$$p = 0.0009 + 0.0094\,j.$$

This means that p/μ and $p\mathbf{r}$ can be neglected by comparison with unity. Under these conditions we have the very simple formulæ

$$\mathbf{Y}_0 = (1 + \mu\mathbf{r})\,\mathbf{Y}_2 \qquad \ldots \quad (10)$$
$$\mathbf{M} = \mu\mathbf{r} \;\ldots \qquad \ldots \qquad \ldots \quad (11)$$

(1).—*Limiting Input Admittance Locus at Audible Frequencies.*

From the form of Equation (10) it is easily seen that the *total* range of variation of $\mathbf{Y}_0$ is the area of the curve corresponding to the limiting circle for $\mathbf{r}$. This circle can be represented vectorially by the equation

$$\mathbf{r} = \frac{1}{2}(1 + \epsilon^{j\theta})$$

where θ can have any value from 0 to 360 deg. From Equation (10) the corresponding locus for $\mathbf{Y}_0$ is the circle

$$\mathbf{Y}_0 = \mathbf{Y}_2\left(1 + \frac{\mu}{2} + \frac{\mu}{2}\epsilon^{j\theta}\right)$$

which is illustrated in Fig. 4 for the representative valve at a frequency of 10,000 cycles, for which

$$\omega C_2 = 3.14 \times 10^{-7}$$
$$G_2 = 3.14 \times 10^{-8}$$
$$Y_2 = \sqrt{G_2^2 + \omega^2 C_2^2} = 3.30 \times 10^{-7}$$

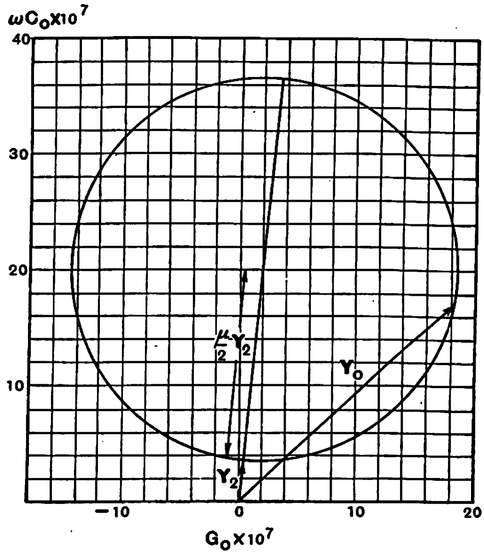

Fig. 4.—*The circular locus for* $\mathbf{Y}_0$ *for pure reactive loads at audible frequencies* ($f = 10{,}000$).

From Fig. 4 it follows at once that the limits of $\mathbf{Y}_0$ are

$$\mathbf{Y}_0\,(\text{min.}) = \mathbf{Y}_2$$
$$\mathbf{Y}_0\,(\text{max.}) = (1 + \mu)\,\mathbf{Y}_2$$

or, putting $\quad \mathbf{Y}_0 = G_0 + j\omega C_0$

G_0 being the input conductance and C_0 the input capacity, it follows from Fig. 4 that

$$G_0\,(\text{max.}) = \left(1 + \frac{\mu}{2}\right) G_2 + \frac{\mu}{2} Y_2$$

$$G_0\text{ (min.)} = \left(1 + \frac{\mu}{2}\right) G_2 - \frac{\mu}{2} Y_2$$

$$C_0\text{ (max.)} = \left(1 + \frac{\mu}{2}\right) C_2 + \frac{\mu}{2} \frac{Y_2}{\omega}$$

$$C_0\text{ (min.)} = \left(1 + \frac{\mu}{2}\right) C_2 - \frac{\mu}{2} \frac{Y_2}{\omega}$$

The numerical values of these limits in the case illustrated are

G_0 (max.) $= 1.84 \times 10^{-6}$ ($1/G_0 = 544{,}000$ ohms).

G_0 (min.) $= -1.46 \times 10^{-6}$ ($1/G_0 = -685{,}000$ ohms).

C_0 (max.) $= 56.5\ \mu\mu$F. (cf. $\overline{1 + \mu} C_2 = 55\ \mu\mu$F.).

C_0 (min.) $= 3.5\ \mu\mu$F. (cf. $C_2 = 5\ \mu\mu$F.)

(Remember that the *total* input admittance quantities can be obtained from G_0 and C_0 by the simple addition of certain valve constants, as shown in para. 5.)

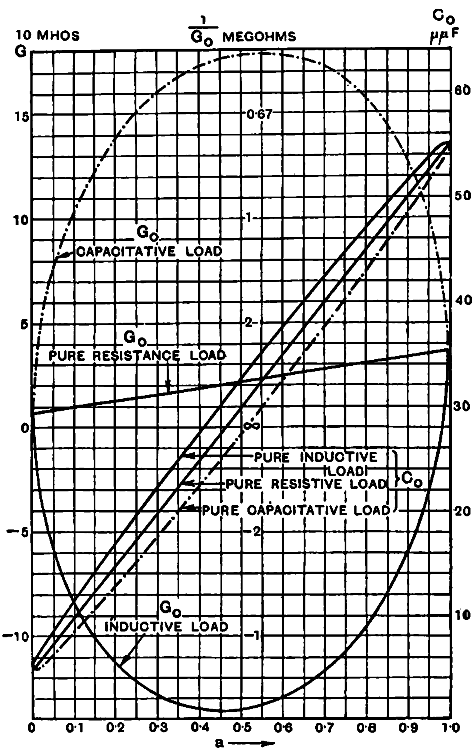

Fig. 5.—*C_0 and G_0. Audible frequency* ($f = 10{,}000$).

9 (2).—*Variation of Input Conductance and Input Capacity at Audible Frequencies.*

Putting $\mathbf{r} = a + jb$ and $\mathbf{Y}_2 = G_2 + j\omega C_2$

then $\quad \mathbf{Y}_0 = \{1 + \mu(a + jb)\}(G_2 + j\omega C_2)$

i.e., $\quad G_0 = (1 + \mu a) G_2 - \mu b \omega C_2 \ldots \quad (12)$

and $\quad C_0 = \frac{\mu b}{\omega} G_2 + (1 + \mu a) C_2 \ldots \quad (13)$

Putting $b^2 = a - a^2$, corresponding to points on the limiting circle for $\mathbf{r}$ (pure reactance loads), it is easy to see that the curves connecting G_0 and C_0 with a are 2nd degree curves. They are, in fact, ellipses, and are shown in Fig. 5 for the representative valve.

The values of G_0 and C_0 corresponding to pure resistance resultant loads are also shown in Fig. 5.

The principal deductions from these curves will be listed at the end of this section.

9 (3).—*Amplification at Audible Frequencies.*

Since $\quad \mathbf{M} = \mu\mathbf{r}$

the locus of $\mathbf{M}$ is a simple multiple of that of $\mathbf{r}$. Actually the magnitude M, given by

$$M = \mu r$$

is the important quantity.

For pure reactance loads

$$r = \sqrt{a} \text{ (see Equation 9)}$$

and for pure resistance loads

$$r = a.$$

The variation of M with a is thus as shown in Fig. 6, which illustrates the general superiority of reactance over resistance loads from the present point of view. The total range of variation of M is the area enclosed by the lines $M = \mu\sqrt{a}$ and $M = \mu a$.

Note particularly that the amplification given by any single valve is not affected by its own inter-electrode capacities except in so far as C_3 *affects* $\mathbf{Z}_5$ (which effect is, in general, very small).

It is the inter-electrode capacities of the following valve, giving rise to a comparatively low admittance shunt across $\mathbf{Z}_4$, which limit the amplification given by the valve.

Note further, that the maximum amplification is μ, but that this requires $\mathbf{Z}_5$ = infinity, a condition which cannot be realised.

It will be shown later that at radio frequencies, the maximum value of M exceeds

μ and corresponds to a load condition which can be realised.

9 (4).—*Principal Deductions* (*Audible Frequencies*).

(*a*) *Input Admittance.* (Not including that of the actual grid-filament capacity.)

(i) The input capacity is always positive and depends more on the magnitude of the load than its phase angle. Its limits are very approximately the grid-anode capacity and $(1 + \mu)$ times this capacity. (The limits may exceed these by a few per cent. on account of the power factors of the inter-electrode capacities.)

(ii) The input conductance is positive for capacitative loads and negative for inductive loads. Its limits are approximately $\pm\mu/2$ times the magnitude of the grid-anode capacity admittance, and are thus approximately proportional to frequency.

(iii) Plotted against the "real" part of the load ratio the curves showing the variation of the input conductance and input capacity are ellipses for pure reactance loads and straight lines for pure resistance loads.

(*b*) *Voltage Amplification.*

(i) The only effect of the inter-electrode capacities on voltage amplification, for a given input voltage, is the shunt effect of the actual anode-filament capacity on the load.

(ii) For a given load magnitude the amplification is higher for a pure reactance load than for a pure resistance load.

(iii) The upper limit of the voltage amplification is the voltage factor of the valve, but this cannot be attained as it implies an infinite load impedance (load factor unity).

10. Deductions from the Network Formulæ at Radio Frequencies.

At radio frequencies the terms in the formulæ are none of them negligible, so that no general approximations are permissible. On general grounds, however, it might be anticipated that at radio frequencies the conductance term in $\mathbf{Y}_2$ becomes unimportant, and there is a certain amount of experimental confirmation of this view.* On this assumption the formulæ take the slightly simpler form

$$\mathbf{Y}_0 = \frac{1 + \mu\mathbf{r}}{1 + jp\mathbf{r}} j\omega C_2 \quad .. \quad (14)$$

$$\mathbf{M} = \frac{1 - jp/\mu}{-1 + jp\mathbf{r}} \mu\mathbf{r} \quad .. \quad (15)$$

where $\quad p = \omega C_2 R_a$

10 (1).—$\mathbf{Y}_0$ *at Radio Frequencies.*

Note first as a confirmation of the formula that when $\mathbf{r} \to 1$

$$\mathbf{Y}_0 \to (1 + \mu)\frac{j\omega C_2}{1 + jp} = (1 + \mu)\frac{1}{R_a + 1/j\omega C_2}$$

i.e., $\mathbf{Y}_0$ tends to the limit $(1 + \mu)$ times

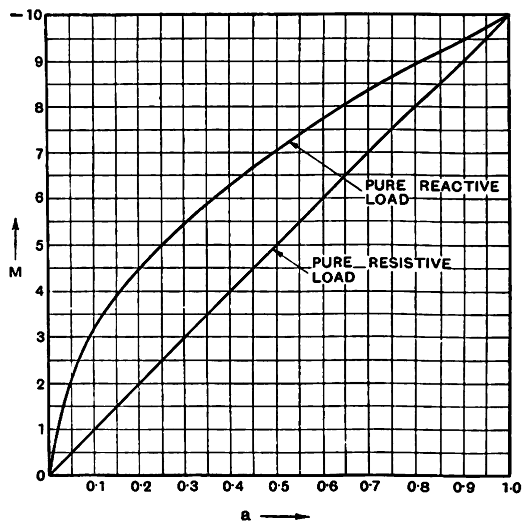

Fig. 6.—*Voltage amplification. Audible frequency* ($f = 10{,}000$).

admittance of C_2 and R_a in series, a conclusion which is obvious from an inspection of Fig. 1.

For a circular locus of $\mathbf{r}$, both numerator and denominator of the expression for $\mathbf{Y}_0$ represent circular loci, and it can easily be shown that $\mathbf{Y}_0$ has also a circular locus. The equation of the circle is rather complicated in form, however, and in the present

* *Proc. Phys. Soc.*, Vol. 40, p. 14 (G. W. Sutton).

instance it will be preferable to take the general case

$$\mathbf{r} = a + jb$$

and analyse $\mathbf{Y}_0$ in terms of its components G_0 and C_0,

i.e.,

$$\mathbf{Y}_0 = G_0 + j\omega C_0 = \frac{1 + \mu(a + jb)}{1 + j\rho(a + jb)} j\omega C_2 \quad (16)$$

from which $$G_0 = \frac{\mu\rho r^2 + \rho a - \mu b}{(1 - \rho b)^2 + \rho^2 a^2}\,\omega\, C_2 \quad (17)$$

$$C_0 = \frac{(1 - \rho b) + \mu a}{(1 - \rho b)^2 + \rho^2 a^2} C_2 \quad (18)$$

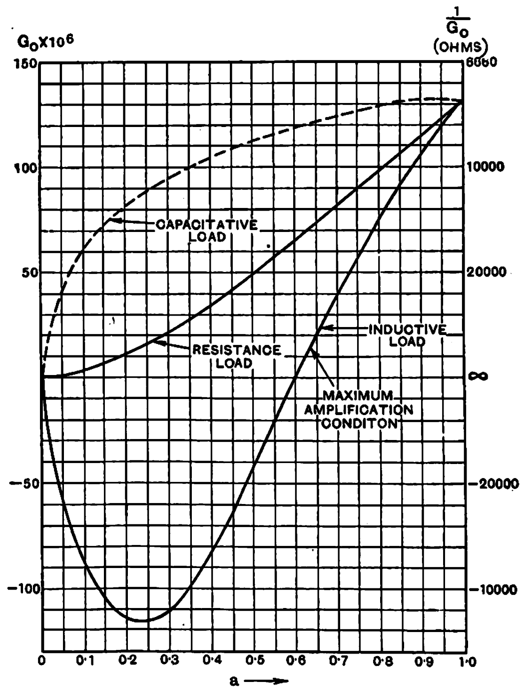

Fig. 7.—G_0 *at* 376.8 *metres* ($\omega = 5 \times 10^6$, $\rho = .75$).

10 (2).—*Input Capacity and Conductance at a Medium Wavelength* ($\lambda = 377$ m.).

At audible frequencies the input capacity and conductance for any given value of a increase or decrease uniformly with b up to the limiting value on the circumference of the load factor circle. In other words, the area of the curve plotted for pure reactance loads includes the total range of values of the input admittance terms. This is no longer true for radio frequencies, though it remains true down to fairly short wavelengths (100 metres or so). However, it appears that in every case the maximum values of G_0, C_0 and M are associated with pure reactance loads. These are the most interesting features of the variation, and pure reactance loads will therefore be considered. The short-wave cases in which the input admittance and voltage amplification have maxima and minima for a given value of a corresponding to points *inside* the limiting circle will be considered in Appendix II.

The variation of C_0 and G_0 with a for pure reactive loads can be calculated from the appropriate forms of Equations (17) and (18), i.e.,

$$C_0 = \frac{(1 - \rho b) + \mu a}{1 - 2\rho b + \rho^2 a} C_2 \quad .. \quad (19)$$

$$G_0 = \frac{(\mu + 1)\rho a - \mu b}{1 - 2\rho b + \rho^2 a}\,\omega C_2 \quad (20)$$

For pure resistance resultant loads ($b = 0$) the appropriate formulæ are

$$C_0 = \frac{1 + \mu a}{1 + \rho^2 a^2} C_2 \quad .. \quad .. \quad (21)$$

$$G_0 = \frac{\rho a\,(1 + \mu a)}{1 + \rho^2 a^2}\,\omega C_2 \quad .. \quad (22)$$

(Remember that these imply loads which are purely resistive when combined with the anode-filament capacity, e.g., tuned circuits. They would not apply exactly to actual resistances in the anode circuit, since the resultant load would not then be purely resistive.)

The variations of G_0 and C_0 for pure reactance and pure resistance resultant loads are shown in Figs. 7 and 8, for a wavelength of 377 metres ($\rho = .75$).

The principal points to note in these curves are listed below :—

(i) The input capacity varies considerably both with the magnitude and the phase of the resultant load, being greater for inductive than for capacitative loads.

(ii) The input capacity reaches a maximum value (slightly greater than $(1+\mu)C_2$ for a *finite* inductive load. It will appear later that this maximum is associated with the maximum amplification condition.

(iii) The input conductance can be positive or negative. It is negative for a certain range of inductive loads reaching

a maximum negative value for a finite inductive load. In the case illustrated the negative input shunt resistance becomes as low as 8,700 ohms. For large effective impedance loads the input shunt resistance is positive but may reach a low figure (about 8,000 ohms in the case illustrated). The input shunt conductance is always positive for a capacitative load.

It would, of course, be possible to calculate the actual critical (maximum and minimum) values of C_0 and G_0 from Equations (19) and (20), but it is found that the analysis becomes

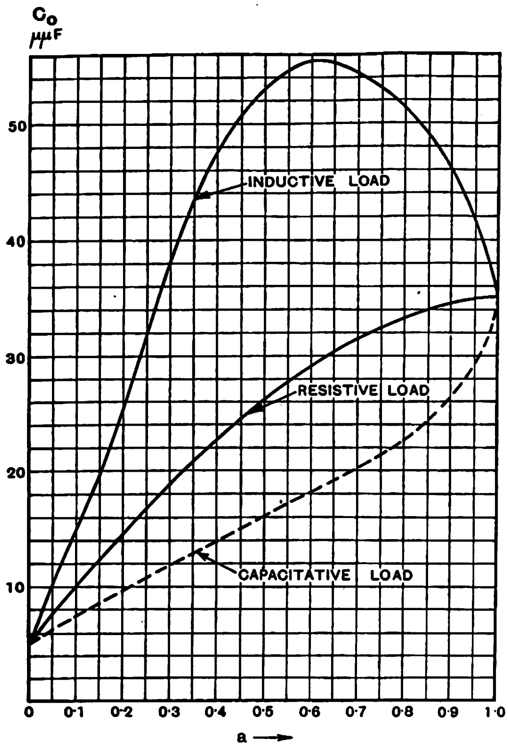

Fig. 8.—C_0 *at* 376.8 *metres* ($\omega = 5 \times 10^6$, $\rho = .75$).

very cumbersome in form and exceedingly difficult to elucidate by a physical interpretation. This step is therefore not given in detail.

10 (3).—*Input Admittance at Short Wavelengths.*

The behaviour of the equivalent network at very short wavelengths (30 metres and less) presents some very peculiar features, which are due to the fact that if ρ is large enough, the denominator $(1 - 2\rho b + \rho^2 a)$ can assume a range of exceedingly small values. For $\lambda = 28.3$, $\rho = 10$ for the representative case chosen. The variations of G_0 and C_0 for this value of ρ are shown in Figs. 9 and 10.

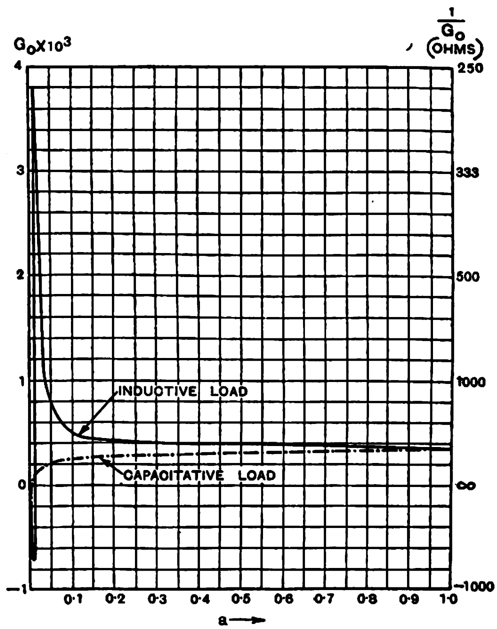

Fig. 9.—G_0 *at* 28.3 *metres* (*pure reactance load*).

Note that for a small value of a (in the neighbourhood of .01) and b positive (i.e., inductive) both input capacity and input conductance show very rapid fluctuations. The input conductance swings from a negative value (corresponding to a negative input resistance of only 1,400 ohms or so) to a large positive value (corresponding to an input shunt resistance of about 260 ohms). Apart from this rapid fluctuation the input shunt resistance remains fairly constant in the neighbourhood of about 5,000 ohms, both for inductive and capacitative loads.

The input capacity shows a similar fluctuation, actually becoming negative, i.e., effectively an inductance, over a small range of values. It must be remembered, however, that C_0 is not the *total* input capacity (*see* para. 5), which is never likely to be negative.

In the absence of experimental con-

firmation, which is not at present available, the above conclusions are put forward with a certain reserve, though an examination of the input admittance formulæ makes the mechanism of these fluctuations quite clear. It is at least reasonable to anticipate that if a triode valve is adequately represented by the usual equivalent network at short wavelengths, those or similar peculiarities in the variation of the input admittance with load may be looked for. Similar irregularities could presumably be produced artificially by increasing the grid-anode capacity so as to obtain a similar high value for ρ at a longer wavelength.

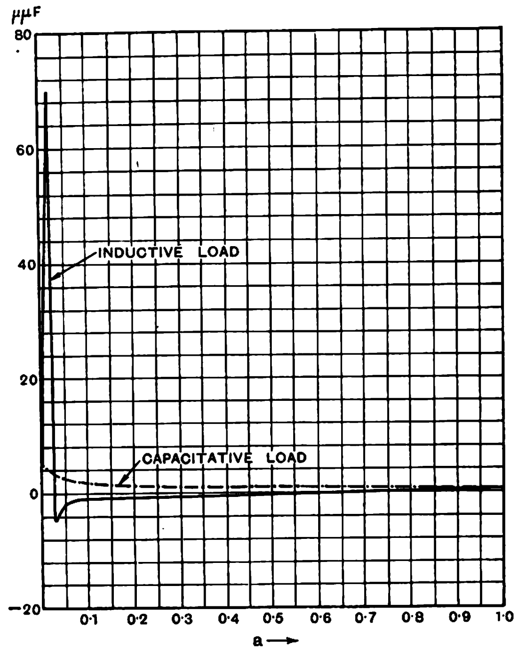

Fig. 10.—C_0 *at* 28.3 *metres* (ρ = 10).

10 (4).—*Amplification at Radio Frequencies.*

The formula for the voltage amplification becomes

$$\mathbf{M} = -\mu\mathbf{r}\frac{1 - j\rho/\mu}{1 + j\rho\mathbf{r}}$$

where $\rho = \omega C_2 R_a$ .. .. (23)

The magnitude of **M** is given by

$$M^2 = \frac{r^2}{1 + \rho^2 r^2 - 2\rho b}(\mu^2 + \rho^2) \qquad (24)$$

The first point to notice is that, as distinct from the audible frequency behaviour of the valve, **M** is considerably affected by C_2.

The important thing to know about the voltage amplification is its maximum value (if any) and the conditions under which it can be obtained.

First, it may be stated (for a fuller explanation, *see* Appendix III) that the maximum value of M will be associated with a pure inductive load. Attention will therefore be confined to this type of variation.

10 (5).—*Maximum Amplification Condition.*

For a pure inductive load formula (24) becomes

$$M^2 = \frac{a}{1 + \rho^2 a - 2\rho b}(\mu^2 + \rho^2) \qquad (25)$$

with $b^2 = a - a^2$.

It is easily shown by the usual differentiation method that this reaches a maximum value (with respect to a) given by

$$M^2 = \mu^2 + \rho^2 \text{ or } M = \sqrt{\mu^2 + \rho^2} \quad (26)$$

when $a = 1/(1 + \rho^2)$ and $b = \rho a$ .. (27)

These conditions can always be fulfilled, since $1/(1 + \rho^2) < 1$.

It is interesting to state this result in terms of the actual resultant anode circuit reactance X_5. From paragraph 8:

$$\frac{X_5}{R_a} = \frac{b}{1 - a} = \frac{\rho a}{1 - a} = \frac{1}{\rho} = \frac{1}{\omega C_2 R_a}$$

i.e., $$X_5 = \frac{1}{\omega C_2}$$

This indicates that the maximum amplification condition is of the nature of a resonance in which the grid-anode capacity plays a part.

From Equation (26) it appears that the voltage amplification can actually *exceed the voltage factor,* this condition being reached with a finite resultant anode circuit load. This should be compared with the behaviour of the valve at audible frequencies, where the voltage factor is the upper limit of the voltage amplification, and this is only attainable with an infinite resultant anode circuit load.

It is only at rather short wavelengths that the excess of the possible amplification over

the voltage factor becomes appreciable. At 283 metres, for instance, $\rho = 1.0$, so that the maximum value of M is 10.05 when μ is 10. On the other hand, for $\lambda = 28.3$, $\rho = 10$ and the maximum value of M is 14.14 for the same value of μ.

The variation of M with a for purely inductive loads is shown in Fig. 11 for wavelengths of 283 and 28.3 metres.

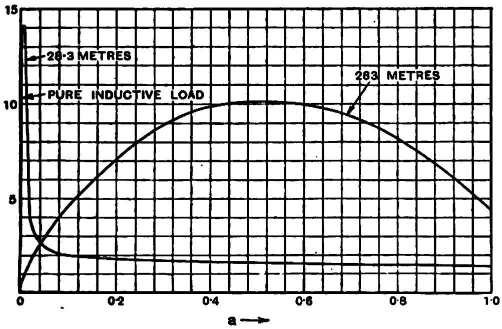

Fig. 11.—*Amplification at 283, and at 28.3 metres.*

It is important to realise that this calculated value of the voltage amplification refers to a maintained applied input potential difference between the grid and the filament, and takes no account of the manner in which the input potential difference is produced. If, as usually occurs in practice, the input P.D. is the resonance voltage across a tuned circuit a much more complicated state of affairs obtains, for this resonant voltage will depend on the input shunt resistance, which itself depends on the anode circuit load. The data for a full analysis of this case are given in this paper, but the matter is not discussed in detail as the paper is confined to the valve network itself without reference to associated input apparatus. In connection with this aspect of the matter, however, the following points should be noted.

10 (6).—*Voltage Amplification and Input Admittance.*

The optimum voltage amplification condition is defined by

$$a = 1/(1 + \rho^2)\ ;\ b = \rho a$$

which implies a pure inductive load. For such a load

$$G_0 = \frac{(\mu + 1)\,\rho a - \mu b}{1 + \rho^2 a - 2\rho b}\,\omega C_2$$

$$C_0 = \frac{(1 + \mu a) - \rho b}{1 + \rho^2 a - 2\rho b}\,C_2$$

For the values of a and b defining the maximum voltage amplification condition these reduce to

$$G_0 = \rho\omega C_2 = \rho^2 G_a = \omega^2 C_2{}^2 R_a$$

and $\quad C_0 = (1 + \mu)\,C_2$

Thus the maximum voltage amplification load gives approximately the maximum input capacity and a fairly low input shunt conductance.

The maximum amplification point is marked on the input capacity and conductance curves for $\lambda = 377$ metres. It is similarly situated on the 28.3 metre curves, but cannot conveniently be shown. It is marked, however, on Fig. 14 (Appendix II). Notice that in both cases the maximum voltage amplification value of a is near the point where the input conductance crosses the axis from negative to positive values, which fact is the probable explanation of the instability associated with tuned circuit H.F. amplification. The actual maximum voltage amplification for a given input voltage is associated with a positive input resistance,

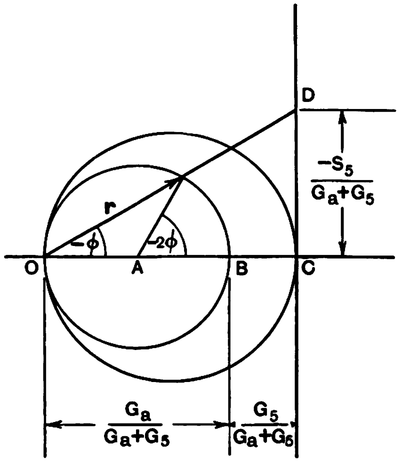

Fig. 12.

i.e., with a stable condition. With a tuned input circuit, however, the resonant P.D. would increase as the input conductance was reduced by making the load inductive reactance smaller, so that the actual response might increase right up to the instability condition.

At short wavelengths the input conductance associated with the maximum amplification condition becomes very high indeed. For instance, at 28.3 metres $\rho = 10$, and for the representative valve, with $R_a = 3 \times 10^4$, the input shunt conductance is $100/(3 \times 10^4)$, corresponding to an input shunt resistance of only 300 ohms. From this it would appear probable that the difficulty of realising high frequency amplification at short wavelengths is not due to the failure of the amplification process itself, but rather to the low input resistance associated with the amplification condition. This aspect of the matter is recommended to the attention of those who are engaged on development work in this sphere.

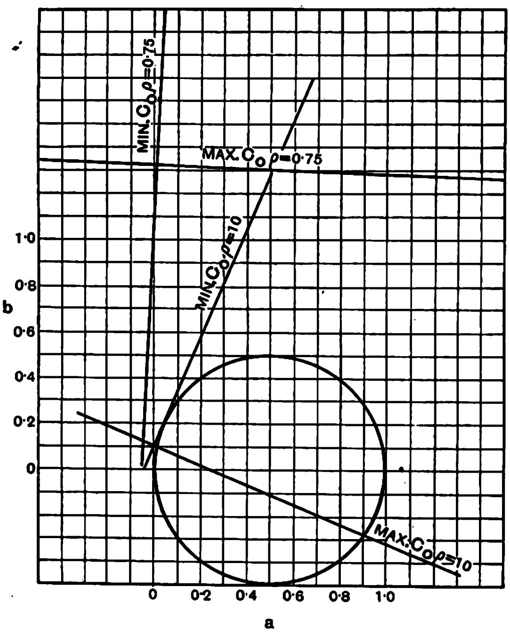

Fig. 13.

APPENDIX I.

Circular Loci of the Load Factor r.

Suppose the load to consist of a variable reactance in parallel with a fixed resistance (e.g., a condenser-tuned " rejector " circuit).

Then $$\mathbf{Y}_5 = G_5 + jS_5$$

where G_5 is constant.

$$\mathbf{r} = \frac{G_a}{G_a + \mathbf{Y}_5} = \frac{G_a}{G_a + G_5 + jS_5}$$

$$= \frac{G_a}{G_a + G_5}\,\frac{1}{2}\left\{1 + \frac{1 - jS_5/(G_a + G_5)}{1 + jS_5/(G_a + G_5)}\right\}$$

$$= \frac{1}{2}\,\frac{G_a}{G_a + G_5}\,(1 + \epsilon^{-2j\phi})$$

where $\tan\phi = \dfrac{S_5}{G_a + G_5}$

Referring to Fig. 12, the locus of **r** is therefore the circle on OB as diameter, becoming the limiting circle when G_5 is zero.

Similarly, if

$$\mathbf{Z}_5 = R_5 + jX_5$$

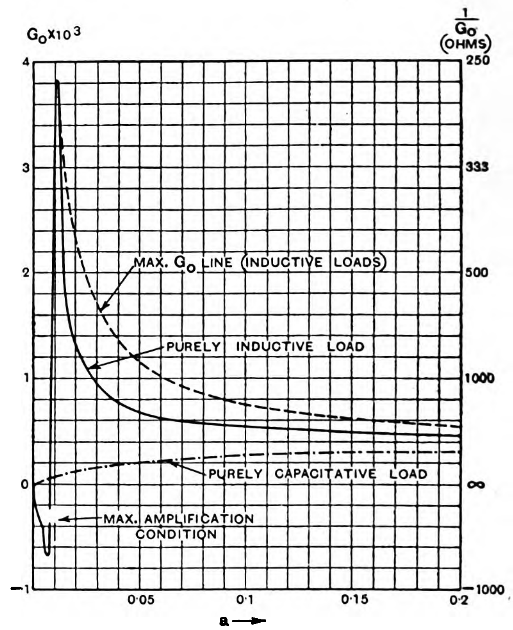

Fig. 14.—*G_0 for 28.3 metres (pure reactance load).*

where R_5 is constant, the circular locus of r is given by

$$\mathbf{r} = \frac{R_5}{R_a + R_5} + \frac{1}{2}\,\frac{Ra}{R_a + R_5}\,(1 - \epsilon^{-2j\psi})$$

where $\tan\psi = \dfrac{X_5}{R_a + R_5}.$

APPENDIX II.

Optimum Input Admittance Lines.

For any given value of a it can be shown by differentiation of 18 with respect to b that C_0 is a maximum or minimum when

$$1 - \rho b = (-\mu \pm \sqrt{\mu^2 + \rho^2})\,a$$

This defines two straight line relationships between a and b, which are shown plotted in Fig. 13 for

$\rho = .75$ ($\lambda = 377$ metres) and $\rho = 10$ (28.3 metres). In the former case neither line cuts the limiting circle, so that the initial values cannot be realised and the maximum realisable values of the input admittance terms correspond to points on the limiting circle. In the latter case the lines do actually cut the circle. For certain values of a, therefore, critical values of the input admittance will be associated with loads that are not purely reactive. The point of intersection of the optimum lines is obviously some kind of discontinuity. This point lies near the circumference of the limiting circle, and accounts for the rapid fluctuation in C_0 observed in this region.

Precisely similar observations can be made with respect to G_0, the optimum lines being

$$1 - \rho b = (\rho \pm \sqrt{\mu^2 + \rho^2})(\rho a/\mu)$$

Fig. 14 shows the variation of G_0 with a for pure reactance loads and also for that part of the maximum G_0 line which lies within the limiting circle. As already pointed out, the optimum G_0 line only affects the value of G_0 over a region which does not include the highest practically attainable value of G_0, which latter is associated with a pure reactance load. This point is of mathematical rather than practical interest, and for that reason is not elaborated in the text.

APPENDIX III.

Optimum Voltage Amplification Lines.

Since $$M^2 = \frac{r^2}{1 + \rho^2 r^2 - 2\rho b}(\mu^2 + \rho^2)$$

it is easily shown that for any given value of a, m^2 reaches a maximum when

$$b = \frac{1 + \sqrt{1 + 4\rho^2 a^2}}{2\rho}$$

increasing with b up to this limit. As in the input admittance cases, the optimum line does not cut the circle for longer wavelengths (i.e., smaller values of ρ) and for such cases the maximum of M corresponds to the highest realisable value of b for a given value of a (i.e., pure inductance loads). For $\lambda = 28.3$ m. ($\rho = 10$) the line actually cuts the circle, as shown in Fig. 15. As before, however, it is found that although for values of a corresponding to the included part of the maximum M line a load which corresponds to the maximum M line (i.e., not purely inductive) gives a higher voltage amplification than a purely inductive

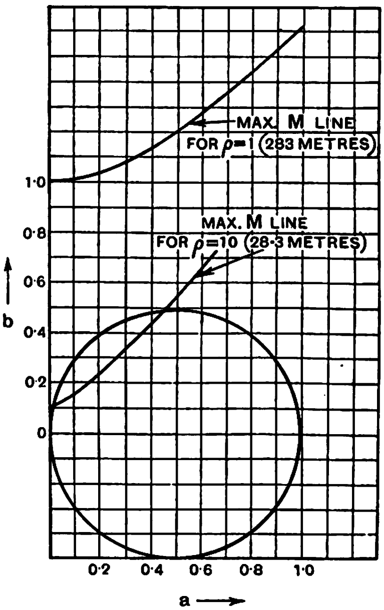

Fig. 15.

load, a higher amplification is obtained for a purely inductive load corresponding to a value of a for which the maximum M line gives an unrealisable value of b just outside the circle. The effect of the maximum M line is, in fact, similar to that shown in Fig. 15 for the input conductance.

Book Review.

Der Bau von Anoden — und Heizstrom — Netzanschlussgeräten. By Manfred von Ardenne. 72 pp., with 78 Figures. Rothgiesser and Diesing, Berlin.

This is a fourth edition, largely rewritten and enlarged. It describes the principles of operation and gives instructions for the construction of practically every known type of apparatus for supplying anode and filament current from the supply mains whether D.C. or A.C. After a general introduction, there are five sections dealing with choke-coils, condensers, resistances, transformers and rectifiers, respectively. Having thus discussed the various components in detail the remainder of the book is devoted to the construction of complete sets of apparatus for D.C. and A.C. mains supply, a subject to which the author has devoted considerable attention. Except for two or three poor photographs the book is well printed and well illustrated and can be recommended to those interested in supplying their receiving sets from the mains—and who is not?

G.W.O.H.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Definition of Selectivity.

To the Editor, E.W. & W.E.

SIR,—I am much indebted to Professor Howe for his comments in the Editorial of *E.W. & W.E.* for August on my proposals with regard to the specification of selectivity and sharpness of tuning, contained in the same issue. He suggests that what he calls the "anomaly" of a two to one ratio between selectivity and sharpness of tuning should be avoided by making the variable circuit element in the latter case one having an approximately linear relation with the frequency (*e.g.*, the square root of the capacity in the simple series resonant circuit), and he supports this suggestion with the statement that the square root of a capacity is, in such a connection, just as fundamental an idea as a capacity.

In reply:—

(1) Selectivity and sharpness of tuning are quite definite and distinct ideas. As pointed out in my article, it is only in certain special and very simple cases that there is any simple numerical relation between them at all, and the two to one relationship which holds in such cases is not really a "highly undesirable anomaly," but, on the contrary, a useful emphasis of the distinction.

(2) It could no doubt be maintained quite logically that the square root of a capacity is just as fundamental an idea as a capacity, but the very words used to describe it show that in the way things have actually developed it is a derived and not a primary idea.

(3) The proposed modification obtains an apparent simplification in some special cases at the expense of complicating the general definition.

Having said this much in legitimate self-defence, I would like to make it clear that I am really quite open to conviction in the matter and would welcome further comment, either from Professor Howe or from anyone else who is interested in this subject. There is no doubt that the term selectivity is somewhat loosely used at present, and my views were put forward mainly with the idea of stirring up comment and suggestion.

F. M. COLEBROOK.

Teddington.

Measurement of Wavelengths of Broadcasting Stations.

To the Editor, E.W. & W.E.

SIR,—With reference to the illuminating account of wavelength measurements by R. Braillard and E. Divoire in *E.W. & W.E.*, p. 412, August, 1929, where the heterodyne note of 1000 cycles per sec. is made to beat with a tuning fork of like frequency, the following may be of interest: If the audio frequency circuit of my modulated C.W. wavemeter (see *W.W.*, p. 107, January 23rd, also *E.W. & W.E.*, p. 83, February, 1929) is replaced by a constant audio E.M.F. injected from a valve driven fork (say) the radio frequency will be modulated by a constant audio frequency of 1000 cycles. The modulated radio frequency from the meter is heterodyned by the incoming signals until a note of 1000 cycles is obtained. The resulting beats between this and the audio note from the wavemeter serve to indicate the constancy of the received station. Such beats can either be recorded or indicated visually on a suitable instrument.

The radio frequency circuit of the meter consists of an inductance and condenser of great accuracy, whilst the potentials applied to the valve are adjusted so that a negligible variation in frequency is introduced by its negative resistance. The valve has preferably a low anode to screen-grid capacity, *e.g.*, 3 micromicrofarads.

Doubtless by injecting the audio E.M.F. at some suitable point in the circuit given by the authors in Fig. 2, similar results could be obtained. The screened valve has, of course, the advantage of greater simplicity.

N. W. MCLACHLAN.

London, 1929.

Anode Rectification.

To the Editor, E.W. & W.E.

SIR,—In his article on Anode Rectification in your current issue, Mr. A. G. Warren states that the method of approximate integration which I described in *E.W. & W.E.* of August, 1927, is unsuitable for the most desirable type of rectification characteristic. He concludes that there is no satisfactory alternative to actual calculation, by which he means the averaging of eighteen selected ordinates. May I suggest that in this opinion he does less than justice to a labour-saving device of tried merit. Indeed, it will be found that if my method be applied to Mr. Warren's own example, its accuracy for the purpose will be amply vindicated.

The formula which I recommended was (*loc. cit.*),

$$i_r = \frac{1}{n}\left\{ i_{\frac{\pi}{2n}} + i_{\frac{3\pi}{2n}} + \ . \ . \ . \ + i_{\frac{(2n-1)\pi}{2n}} \right\}$$

where the phase angles are reckoned from the extreme minimum of the voltage variation, i.e., from $-E$. If, now, n be put $= 3$, a simple calculation shows that, in accordance with Mr. Warren's scheme of reckoning the angles from a central zero,

$$i_r = \frac{2}{3} \times \left(\frac{i_1 - i_2}{2}\right)$$

where the value of the bracket factor is that corresponding to the value $\theta = 60°$ in Mr. Warren's table. To test the accuracy of this result, I tried to interpolate for $\theta = 60°$ from the values there given. It was, however, impossible to do so to four-figure accuracy, as the values do not difference smoothly. This seems to indicate that the accuracy implied in Mr. Warren's example is somewhat illusory, the fourth significant figure being quite

untrustworthy. Taking, however, the value of $\frac{i_1 - i_2}{2}$ required as the mean of those given for 55° and 65°, it is found that i_r is .0567 mA. as compared with Mr. Warren's .0565 mA., surely not a bad shot! Indeed, it is difficult to see what more could be required, in view of the uncertainty attaching to the fourth place of the figures given.

It is only fair to my formula to restate the condition under which it applies. This is, that the $2n$th differences of the characteristic function shall be zero. This expressly rules out the ideal "angle" characteristic, but even when $n = 3$ it certainly admits most of the experimental characteristics likely to be met with in practice. The course of such a characteristic over a wide range may well be set out from six experimentally determined points, and thus be represented by a polynomial function of the fifth degree whose sixth differences are zero. (The fact that more than six points may actually be taken only indicates the necessity for "graduating" the data, to which a smooth curve of the fifth degree will then be adequate.)

Should the standard of accuracy required be even higher than this, the value of n may be increased so as to ensure a still more representative arc of the curve. For example, if $n = 6$, we shall have in Mr. Warren's notation

$$i_r = \frac{1}{3}\left\{\left(\frac{i_1 - i_2}{2}\right)_{15^\circ} + \left(\frac{i_1 - i_2}{2}\right)_{45^\circ} + \left(\frac{i_1 - i_2}{2}\right)_{75^\circ}\right\}.$$

These values are given in his table, so that the calculation stands as under

$$\begin{array}{r} .0081 \\ .0600 \\ .1007 \\ \hline 3).1688 \\ \hline .0563 \end{array}$$

Surely the saving of labour even here is considerable, while the accuracy is unimpeachable. Indeed, the error introduced by the approximation is infinitesimal compared with the observational errors in the data to which it is here applied.

It is pertinent to observe that, if we could be assured of the *absolute* accuracy of the data in his table, Mr. Warren's longer method would be justified. Failing this, however, we are entitled to use any method of approximation whose intrinsic error lies well within the standard of error of the data used. I think it will be found that the standard of accuracy obtained by putting $n = 3$ in my formula is considerably superior to that of the determination of most experimental characteristics, while with $n = 6$ the accuracy is beyond all cavil. To put $n = 18$, which is essentially his procedure, is simply to multiply labour for no useful purpose.

In conclusion, may I say that I do not quite see the "obvious simplification" attained by plotting the curve of $\frac{i_1 - i_2}{2}$. To my mind nothing is gained by finding the means of nine pairs of ordinates and then finding the average of the nine means. Why not average the complete set of eighteen from the original curve? Setting out the new graph only introduces a fresh source of error, and there is no reason why the original curve should not be drawn to as large a scale as may be necessary. I cannot help thinking that, working to four-figure accuracy, it would have been better to dispense with this device. W. A. BARCLAY.

Bieldside, N.B.

Frequency Modulation.

To the Editor, E.W. & W.E.

SIR,—After consideration of Mr. Holmblad's reply in the August issue, I am forced to the conclusion that my formula for a frequency-modulated wave is an impossible one. It is now clear that in the expression

$$i = a \sin(\omega t + \phi) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

for an ordinary sine wave, ω represents the cyclic frequency not because it is the multiple of t but because it is the differential coefficient of the angle $\omega t + \phi$. When ω or ϕ is a function of t, ω ceases to represent the cyclic frequency at the instant t, and the correct expression for this frequency is $\frac{d}{dt}(\omega t + \phi.)$

To deduce the formula then for a frequency-modulated wave, it may first be written in the form

$$i = a \sin\{f(t)\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

The instantaneous frequency $\frac{df}{dt}$ is to vary sinusoidally between limits $\omega + km$ and $\omega - km$, so that

$$\frac{df}{dt} = \omega + km \cos mt.$$

By integration

$$f(t) = \omega t + k \sin mt + \theta.$$

If time is measured from a zero point where $i = 0$, then θ vanishes and (2) becomes

$$i = a \sin\{\omega t + k \sin mt\} \quad \ldots \quad \ldots \quad (3)$$

which agrees with the formula employed by Mr. Holmblad.

On comparing (3) with (1) it is seen that the frequency-modulated wave may be regarded as one in which the phase angle ϕ has a slow cyclic variation $k \sin mt$. Methods known as "phase modulation" have been proposed in which a fixed-frequency wave is modulated by a phase-adjusting impedance. It would appear that the wave resulting from such "phase modulation" is of the same form as that produced by "frequency modulation."

Readers interested in the subject should refer to an article by John R. Carson in the Proceedings of the American Institute of Radio Engineers, Vol. 10, page 57. The subject is approached in a somewhat different manner but the conclusions arrived at with regard to the width of the sidebands agree with those of Mr. Holmblad.

G. H. MAKEY.

The Patent Office.

Abstracts and References.

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PROPAGATION OF WAVES.

Sur la Couche Ionisée de la Haute Atmosphère (The Ionised Layer of the Upper Atmosphere).—M. Ponte and Y. Rocard. (*L'Onde Élec.*, May, 1929, V. 8, pp. 179–191.)

Authors' summary :—" In problems relating to the conducting properties of the upper atmosphere, it seems that up to now one has been satisfied with a distinctly summary kinetic theory for calculating fundamental values such as the free paths of the electrons. We attempt in this article to arrive at new values taking more strict account of the interactions between electrons and molecules. It will be seen that we thus reach results differing considerably from those usually admitted, since we find a value for the electron free path which is (other things being equal) 40 to 160 times smaller than that deduced from the elementary theory. It must be understood that these results are only valid for electrons possessing the velocity of thermal agitation, which is the case for the electrons of the higher atmosphere—apart from the influence of the earth's magnetic field. As soon as electrons become accelerated—however little—by an electric field, the interactions with molecules become negligible and the free paths increase."

The next part of the paper will discuss the consequences of the above conclusion as it affects the Heaviside layer and its behaviour towards different wavelengths.

Group Velocity.—D. G. Bourgin. (Summary in *Phys. Review*, June, 1929, V. 33, p. 1072.)

The empirical formula suggested by Tonks (May Abstracts, p. 265), namely, $\mu E = vE_i$, where μ and v are the group and phase velocities and E and E_i are the total and doubled reactive energies per unit length respectively, is examined for validity. The theorem does not hold in general if the characteristic linear differential equation involves higher space derivatives than the second—the physical interpretation is immediate.

Über die Absorption Hertzscher Wellen in ionisierten Gasen (The Absorption of Hertzian Waves in Ionised Gases).—H. Dänzer. (*Ann. der Phys.*, 7th June, 1929, 5th Series, V. 2, No. 1, pp. 27–62.)

An investigation arising from an attempt to imitate on a small scale the effects of the Heaviside layer on electromagnetic waves. 4–4.5 cm. waves were generated by a spark dipole oscillator (after Lebedew) and directed by an optical system of paraffin lenses. Reception was by a bolometer system (balanced bridge), a length of Wollaston wire being reduced at its mid-point, the un-reduced ends acting as the poles of the receiving dipole. The rays were directed against a " layer " of intensively ionised gases (Ne, A, N, H, O and Air) and reflection and absorption measurements were made. Using the absorption effect thus measured as a method of investigation, the writer then measured the life of the free electrons produced by the ionising discharge. Values for the various gases ranged from about 3×10^{-4} sec. (H and N) to 1×10^{-4} sec. (Air and O). The theoretical section of the paper appears to be similar to the treatment of the subject (from considerations regarding the propagation of waves) by H. Lassen (*Zeitschr. f. Hochf. Tech.*, 1926, V. 28, p. 139).

Magnetic Storms and Radio Signals.—I. J. Wymore. (*Nature*, 20th July, 1929, V. 124, p. 109.)

A paragraph quoting the announcement that the Bureau of Standards have discovered the following relation between magnetic storms and radio signals:—when signals from European stations are weaker than usual and those from nearer stations in America are louder than usual, magnetic storms may be expected within a few days. After a magnetic storm, much stronger signals are received from distant stations.

Some Observations of Short Period Radio Fading.—T. Parkinson. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1042–1061.)

Author's summary :—" The data presented are the product of an investigation started at the beginning of 1928 with the object of studying the short-period fading of radio broadcast transmissions. Particular attention was paid to those intensity changes which take place during periods ranging from a few seconds to several minutes. Various antenna combinations were used in making simultaneous records in order to separate the effects of various causes of fading.

" The data secured partly confirm the conclusions of previous investigations, partly point to other sources of fading. Varying intensity of the indirect ray and interference between indirect and ground rays are evidenced as in earlier experiments, but rotation of the plane of polarisation of the indirect ray is also shown to be a considerable factor and there are suggestions of lateral direction shifts of the indirect rays and of their arrival by multiple paths."

The paper is followed by an appendix giving a summary of the conclusions of other workers from previous investigations.

A New Method of Determining Height of the Kennelly-Heaviside Layer.—C. B. Mirick and E. R. Hentschel. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1034–1041.)

Field strength measurements of signals from aeroplanes, recorded during the past year at the Naval Research Laboratory, Washington, showed

periodic variations of fairly constant frequency over considerable time intervals. The measurements were on frequencies 2,500–6,000 kc. per sec., at distances up to 130 miles; in most cases marked fading was observed at distances beyond 15 or 20 miles.

From data thus obtained (which included velocity of aeroplane over the ground, distance from recording station, and distance between peaks of fading) a determination of the height of the Heaviside layer has been attempted, on the following theory. As the transmitter moves from or toward the receiver, the ratio of the length of the ground path to the sky path is changing, and the phase relation between the two components is also progressively changing; while the aeroplane travels over a distance V/F (V = velocity parallel to ground, to or from recording station; F = frequency of intensity variation), the graphic record goes from peak to peak, and the phase of one component has changed 360 degrees with respect to the other—*i.e.*, the difference between the optical lengths of the two paths has changed by a distance equal to the wavelength of the transmitted wave.

The data from a number of flights have been treated according to this theory. In practically every case the distance between maxima of fading was found to increase with the distance of transmission, which conforms with the theory and its geometrical representation. The values for the layer height varied from 53.4 to 85.0 miles, the mean of 11 tests working out to approximately 70 miles (113 km.). All these tests were in daytime, and were on either 2,725 or 3,000 kc. per sec.

Fading and Skip Distance in the Dutch East Indies.—S. G. Langendam. (*Tijds. Ned. Radiogen.*, December, 1928, V. 4, pp. 3–12.)

For average telephonic ranges of 400 km. the best wavelengths were 70–80 m., showing little fading between 11 a.m. and 2 p.m. Skip distance effects seemed completely absent.

The Ozone in the Earth's Atmosphere.—D. N. Harrison. (*Nature*, 13th July, 1929, V. 124, pp. 58–61.)

"Ozone observations are now made regularly at least once a day at about half a dozen places in different parts of the world. The results up to the present from these series of observations are the subject of this article."

Thermal Diffusion of Rare Constituents in Gas Mixtures.—S. Chapman. (*Phil. Mag.*, January, 1929, V. 7, pp. 1–16.)

The Attenuation of Ultra-Violet Light by the Lower Atmosphere.—L. H. Dawson, L. P. Granath, and E. O. Hulburt. (*Phys. Review*, 1st July, 1929, V. 34, pp. 136–139.)

Among the results may be mentioned:—The absorption around 2,800–2,900 A.U. was not sufficient to account for the sharp cessation of the solar spectrum in this region (this is in keeping with the belief that the ultra-violet limit of the solar spectrum is due to ozone in the high atmosphere). The absorption in the lower atmosphere at 2,200–2,050 A.U., a spectrum region where ozone is relatively transparent, is great enough to prevent sunlight of these wavelengths from penetrating to sea level.

Reception Experiments in Mount Royal Tunnel: Discussion.—C. R. Englund: A. S. Eve. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 892–894.)

Referring to the paper dealt with in May Abstracts, p. 263, Englund mentions that Eve spoke of radio methods of ore prospecting, and points out that the attenuation in the ground which Eve reports as observed for ordinary radio signals is not necessarily the same attenuation as that which the ore prospector would encounter in applying radio to subterranean ore finding. In the latter process it would seem that ordinary transverse waves are the preferable type, such for example as would best be produced and observed by using buried aerials. In these waves the electric and magnetic vectors are not in time phase (because of the earth's conductivity) but are at right angles to the Poynting vector, and the only serious difference from ether waves is the presence of an attenuation factor. Ordinary radio transmission is another type of wave motion, a longitudinal one. The equiphase surfaces no longer coincide with the equiamplitude surfaces, and there is attenuation in directions both along and perpendicular to the ground. That the attenuation perpendicular to the ground in these "hybrid" waves should be the same as the attenuation along the direction of propagation of transverse waves is neither necessary nor evident and a distinction is clearly to be made. He then elaborates this point both mathematically and by quoting experimental results.

Range Tests with Waves under One Metre in Length.—W. Ludenia. (*See* under "Transmission.")

Beam Telephony on 14 cm. Waves.—K. Kohl. (*See* under "Transmission.")

La Pénétration des Déplacements Électriques ou magnétiques ainsi que des Ondes Électromagnétiques à la Surface de Séparation de deux Milieux (The Penetration of Electric or Magnetic Displacements, or of Electromagnetic Waves, at the Surface of Separation of Two Media). —A. K. Kotelnikoff. (*Rev. Gén. de l'Élec.*, 13th July, 1929, V. 26, pp. 53–59.)

Starting with the fundamental equations defining the propagation of any sinusoidal displacement, the writer investigates the modifications which their general solutions undergo at the surface of separation of two unlike media. The expressions thus established are then applied in succession to the cases where the displacements are electric, magnetic, and finally when they are electromagnetic waves. "The resulting simple relations and their graphic representation allow a physical interpretation to be placed on the phenomena under consideration."

C

A NOTE ON DOPPLER EFFECT AND THE HYPOTHESIS OF RADIATION QUANTA.—D. S. Kothari. (*Phil. Mag.*, July, 1929, V. 8, No. 48, pp. 55–63.)

"The Doppler-Fizeau effect . . . is easily explained if radiation is considered to be propagated in the form of waves. In the present note it is explained on the hypothesis of radiation quanta, *i.e.*, light is considered to be propagated in the form of quanta and not waves. It is further shown that Compton effect is a particular case of Doppler effect." The writer ends his paper by pointing out that the Majorana experiment can now be regarded as proving the constancy of the velocity of light both on the wave theory and on the quantum theory.

ÜBER DIE KALORIMETRISCHE ABSOLUTMESSUNG DES ELEKTROLYTISCHEN LEITVERMÖGENS FÜR HOCHFREQUENTEN WECHSELSTROM (On the Calorimetric Absolute Measurement of Electrolytic Conductivity for High-frequency Currents).—E. Justi. (*Ann. der Phys.*, 7th June, 1929, Series 5, V. 2, No. 1, pp. 65–93.)

As an example of the results, the behaviour of a NaCl solution (about 9.2 per cent.) may be given :—The comparative resistance values for various wavelengths were roughly 56 (50 m. wave), 23 (75 m. wave), 13 (100 m. wave) and 8 (120 m. wave). Thus within this range of frequencies there is no large sudden change in conductivity such as might be expected (somewhere between L.F. oscillations and light frequencies) to reconcile the transparency of many electrolytes with Maxwell's theory, which demands opacity as a condition for conductivity. Among results obtained in preliminary experiments, the writer concludes that the increase of resistance caused by surrounding a wire carrying a H.F. current with an insulating coating is probably not due to dielectric loss in that coating (as is usually assumed) but to the latter's higher dielectric constant, causing a more pronounced skin effect.

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS.—A. D. Ladner. (*Marconi Rev.*, June, 1929, No. 9, pp. 1–8.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

COSMICAL MAGNETIC PHENOMENA.—S. Chapman. (*Nature*, 6th July, 1929, V. 124, pp. 19–26.)

The Rouse Ball Lecture delivered at Cambridge on 31st May. It is divided into the following sections :—Lunar and Planetary Magnetism ; Terrestrial Magnetism ; Solar Magnetism ; Origin of the Magnetism of the Earth and Sun ; the Electrical Conductivity within the Earth ; Radial Limitation of the Sun's Magnetic Field ; Terrestrial Drift Currents and other Electromagnetic Phenomena. In this last section, the writer says : "Eastward drift currents will flow at heights where the mean free path is larger than, or comparable with, the spiral-radius of ions and electrons ; in the earth's field, at the equator, the spiral-radius is about 2 cm. for an electron, and 5 metres for an ionised oxygen or nitrogen molecule ; consequently *electronic* drift currents will occur at heights above about 70 km., and *ionic* drift currents above about 150 km. But the number of electrons and ions is much less than would be required to enable the drift currents to shield the outer space from the earth's magnetic field ; less than 5 per cent. of the tubes of force crossing the earth's surface are confined within the atmosphere by the drift currents. This estimate is derived from the spherical harmonic analysis of the earth's field, which shows that only about 3 per cent. of the surface intensity is due to overhead currents ; from this it is possible to infer that there are less than 10^{16} ions per sq. cm. column of atmosphere, above a height of 150 km."

DIE RADIALE BEGRENZUNG DES MAGNETFELDES DER SONNE (On the Radial Limitation of the Sun's Magnetic Field).—J. Bartels. (*Naturwiss.*, 12th April, 1929, V. 17, pp. 243–244.)

A communication on the subject of Chapman's paper referred to in July Abstracts, p. 387.

VARIATION DIURNE DU POTENTIAL ÉLECTRIQUE DE L'AIR ET DÉPERDITION ÉLECTRIQUE PENDANT LE MOIS DE SEPTEMBRE, 1928, À L'OBSERVATOIRE DE KSARA — LIBAN (Daily Variation of Atmospheric Electric Potential and Electric Dissipation Loss during September 1928, at Ksara, Liban).—J. Chevrier. (*Comptes Rendus*, 13th May, 1929, V. 188, pp. 1306–1307.)

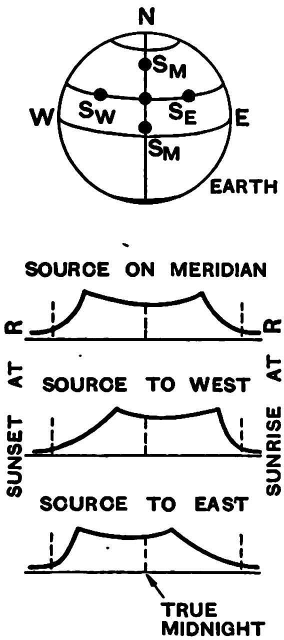
UN PROCÉDÉ POUR DÉTERMINER À GRANDE DISTANCE LA POSITION GÉOGRAPHIQUE ET LA VITESSE DE CERTAINES DISCONTINUITÉS OU PERTURBATIONS MÉTÉOROLOGIQUES À L'AIDE DES ATMOSPHÉRIQUES QU'ELLES ÉMETTENT (A Method of Determining from a Great Distance the Geographical Position and the Velocity of Certain Meteorological Discontinuities or Disturbances, by Means of the Atmospherics which these Emit).—J. Lugeon. (*Comptes Rendus*, 24th June, 1929, V. 188, pp. 1690–1692.)

Deductions from 550 days' atmospheric registrations taken at Zurich with the writer's "atmoradiograph," which records the frequency per minute of the disturbances and gives an idea of their intensity by the thickness of the line traced (see *Ac. Soc. Helvétique Sc. Nat.*, 109th Session, Lausanne, 1928, p. 141).

The writer divides atmospherics into the usual two classes—*local*, short range (a few hundred metres to a few kilometres), not susceptible to D.F., almost always attributable to local meteorological causes and thus giving an indication of the quality and geographical origin of the air in circulation there ; and *distant*, capable of being D.F.'d, of range reaching several thousands of kilometres, emanating chiefly from discontinuities where the cold or polar air is "active." The range of these atmospherics is greatest in the dark, least in the illuminated, portion of the atmosphere. Registration is remarkably regular, suggesting a filtering or absorptive effect along the path of the waves. The differing properties of the two classes allow them to be distinguished one from the other in those cases where the two are superposed.

The régime of the distant atmospherics, received in complete darkness, is established gradually after sunset at the place of origin. Their first maximum is reached a little after the end of the astronomical twilight there—when the last solar ray has left the "mirror of reflection of the Hertzian waves." Inversely, from the moment when the first rays of the solar aurora point to the zenith of the place of origin or of the receiver (according to whether the latter is W. or E. of the former), long-distance propagation of atmospherics is progressively diminished and finally annulled when the whole path is in daylight.

A minimum of intensity of distant atmospherics occurs when the sun is opposite to the meridian of the receiver—at midnight. "This is due to the *tide* of the Heaviside layer, which at that time is at its highest point so that the path is at its maximum length, with a consequent weakening of received field."



The next part of the paper deals with the deduction, from the shape of the records, of the position of the source of the distant atmospherics.

Thus in the diagram if S_M is a source on the meridian of the receiver R, the recorded curve will be symmetrical with respect to true midnight, since the twilight phases are the same at S and R. If the source is at S_W, west of R and practically on the same parallel of latitude, the cessation of distant atmospherics will occur after sunset at R, with a time-lag equivalent to the time-difference between twilight at R and S: for a source to the east, the curve will be displaced in the reverse direction. The longitude of S is thus given by the last nocturnal maximum, corresponding to the end of the night at the source.

The rest of the paper is devoted to showing how a comparison of these curves, day after day, gives a means of measuring the average velocity of displacement of a source, and an indication of its importance.

Comets and Terrestrial Magnetic Storms.—H. B. Maris and E. O. Hulburt. (*Phys. Review*, June, 1929, V. 33, pp. 1046–1060.)

See May Abstracts, p. 265, on the "ultra-violet blast" theory in its relation to comets. Evidence in support is here provided by data concerning 31 comets between 1848 and 1927. In the month preceding each comet's activity there occurred on the average 6, 4, 2.9 and 1.5 times as many magnetic storms of strength 4, 3, 2 and 1 respectively, as should have occurred according to chance.

Sur l'Accélération des Masses d'Air dans les Mouvements atmosphériques (The Acceleration of Masses of Air in Atmospheric Movements).—L. Petitjean. (*Comptes Rendus*, 24th June, 1929, V. 188, pp. 1688–1690.)

By thermodynamic methods, making use of a relation due to Margules, the writer obtains an equation to give the sense of the acceleration in question. Applying this to the air in the northern hemisphere, he finds 4 possible cases, two of which are subdivided into two possibilities (accelerated and retarded motion). An example of these 4 cases is given by the first:—the air rises, turning to the left; the movement is retarded. This case occurs when "passive" warm air is thrown on the left of the "active" cold air following the surface of a cold front.

Elektromagnetische Storungen II (Atmospherics. Part II).—F. Schindelhauer. (*E.N.T.*, June, 1929, V. 6, No. 6, pp. 231–236.)

Further elaboration of the author's theory dealt with in February Abstracts, pp. 101–102. The final summing-up is as follows:—The available observations lead to a grouping of "ring-stream" disturbance which agrees with the actual direction of the magnetic field. The daily variation of the direction in Aboukir is "in principle" the same as in Potsdam (p. 232, r-h. column). During the day an ionised layer moves between the earth's surface and the "ring-stream" layer, acting as a screen and itself forming a source of disturbance (*cf.* Lugeon, August Abstracts). The electrical equilibrium processes in this layer take place along the lines of magnetic force, since the free paths are short (p. 233, l-h. column). In the afternoon the two layers merge into one another, with the result that as ionisation decreases a gradual rotation of the (magnetic) N-S direction towards the (magnetic) E-W direction takes place, apparently following the course of the sun (p. 234, l-h. column). The ionisation in the day-layer in the morning, and the recombination in the afternoon, take place from below upwards. The influence of the displacement of the earth's magnetic axis relative to the axis of rotation is seen in the daily variation of the direction (p. 234, r-h. column).

Überlagerung des Newtonschen Feldes durch ein Coulombschen Feld (The Superposition of an Electric Field on the Newtonian Field).—G. v. Gleich. (*Zeitschr. f. Phys.*, 13th June, 1929, V. 55, No. 5/6, pp. 378–385.)

Many phenomena, such as the behaviour of comet tails, suggest that the sun is the mid-point not only of a gravitational field but also of an electrical field. The writer sets out to find how great an electric charge the sun must have in order to produce the much-argued-over perihelion-

displacement of Mercury. He concludes that a particle of sun- and planet-substance, of the mass of an electron, would have to carry a charge greater than 4.66×10^{-31} e.s.u., which he considers reasonable in comparison with the known charge of an electron.

A final note suggests that the sun's electromagnetic field—if it exists—may undergo variations in strength which perhaps might be connected with sunspot frequency: this idea recalls Ludendorff's work on the dependence of the shape of the solar corona on the sunspot frequency.

DURCHLÄSSIGKEIT DER ABSOLUT REINEN UND TROCKENEN ATMOSPHÄRE FÜR SONNENSTRAHLUNG (Transparency of the Absolutely Pure and Dry Atmosphere for Solar Radiation).—W. Kastrow. (*Meteor. Zeitschr.*, No. 10, 1928, V. 45, pp. 377–381.)

Basing his calculations on the recent determination at Mt. Wilson of the energy-distribution in the solar spectrum, and proceeding by a different mathematical path to that usually followed, the writer obtains values disagreeing quite seriously with those of Linke and Fowle.

BROADCASTING OF SYNOPTIC WEATHER CHARTS.—(*Nature*, 6th July, 1929, V. 124, p. 30.)

A paragraph on the present broadcasting from 5XX of weather charts for reception on picture receivers.

EINE BEMERKUNG ÜBER DIE ABHÄNGIGKEIT DER MAXIMALEN HIMMELSPOLARISATION VON DER SONNENHÖHE (A Note on the Dependence of the Maximum Sky Polarisation on the Height of the Sun).—J. J. Tichanowsky. (*Meteor. Zeitschr.*, No. 12, 1928, V. 45, p. 480.)

SUNSPOTS AND PRESSURE.—M. V. Unakar. (*Nature*, 6th July, 1929, V. 124, pp. 11–12.)

INTERNATIONAL CO-OPERATION FOR AURORAL RESEARCH.—C. Störmer. (*Journ. Roy. Astron. Soc. Canada*, January, 1929, V. 23, pp. 1–7.)

The photographic methods used in the work referred to in April and August Abstracts, pp. 204 and 445, are here described, and a plan for international co-operation is discussed.

PERIODS OF SOLAR AND TERRESTRIAL PHENOMENA.—H. Fritz. (*Monthly Weather Rev.*, October, 1928, V. 56, pp. 401–407.)

VARIATIONS DU CHAMP ÉLECTRIQUE TERRESTRE À LA STATION DU SOMMET DU PUY DE DÔME (Variations of the Terrestrial Electric Field at the Puy de Dôme Summit Station).—E. Mathias and Ch. Jacquet. (*Comptes Rendus*, 1st July, 1929, V. 189, pp. 14–15.)

COMPTE RENDU DES OBSERVATIONS RADIOATMOSPHÉRIQUES FAITES PENDANT L'ANNÉE 1927 (Report on the Observations of Atmospherics during 1927).—D. B. Paolini and G. P. Ilardi. (*L'Onde Élec.*, May, 1929, V. 8, pp. 222–226.)

A paper communicated to the U.R.S.I. Congress in 1928. The observations were based on the Paolini atmospheric-scale, which includes 14 degrees of which 8 distinctly interfere with reception; four of these (group I) represent "distinct" atmospherics which can be easily counted, while the other four (group II) represent the "confused" type. A summarised analysis of the monthly "density" of each of these two groups is given.

DIE ERZEUGUNG WEITGEHEND HOMOGENER MAGNETFELDER DURCH KREISSTRÖME (The Formation of Extensive Homogeneous Magnetic Fields by Circular Currents).—G. Fanselau. (*Zeitschr. f. Phys.*, 4th April, 1929, V. 54, No. 3/4, pp. 260–269.)

A more complex form of the usual Helmholtz coil presents great advantages over the latter and should be useful for measuring terrestrial magnetism.

ZUR FRAGE DES TÄGLICHEN WINDGANGES (The Question of the Daily Variations of Wind).—B. Iswekow. (*Meteorol. Zeitschr.*, No. 1, 1929, V. 46, pp. 1–7.)

PROPERTIES OF CIRCUITS.

ÉTUDE DE LA MÉTHODE DE BEATTY POUR LA MESURE DE L'AMPLIFICATION D'UN ÉTAGE À RÉSONANCE (An Investigation of Beatty's Method of Measuring the Amplification of a Tuned Stage).—F. Bedeau and J. de Mare. (*L'Onde Élec.*, May, 1929, V. 8, pp. 210–221.)

Authors' summary:—"The calculation of the amplification of a tuned stage has been dealt with by a number of writers. Simplifying assumptions are generally made which in spite of their apparent legitimacy considerably affect the accuracy of the results. Beatty's method (*E.W. & W.E.*, January, 1928) although very simple, gives a much more accurate calculation of the amplification. Now that tuned amplifiers with screen-grid valves are being more and more used, it seems of interest to discuss Beatty's paper, which acts as a guide to the choice of valves. . . . We pass over that part of the paper dealing with future progress with screen-grid valves, and have on the other hand developed the paragraph on the study of stability."

Regarding the determination of the valve constants which must be obtained, the writers do not recommend Miller's method of measuring the amplifying power K and internal resistance ρ, but prefer a direct determination of the latter by a Wheatstone bridge. The slope $S (= K/\rho)$ is then measured directly by Barkhausen's method (of which a diagram and summary are given). The grid-plate capacity they find by the method of Hull and Williams (diagram and summary also given).

LA QUESTION DE L'AMPLIFICATION (The Question of Amplification).—P. Olinet. (*QST Franç.*, June, 1929, pp. 12–17.)

In this continuation of the series, the first parts of which were referred to in October Abstracts, 1928, the writer deals with the practical production

of negative resistances, taking as examples the two two-triode combinations known as Turner's Kallirotron and Scott-Taggart's Biotron, both of which he analyses.

VERSTÄRKERTRANSFORMATOREN (Amplifier Transformers).—M. Osnos. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 39–58.)

A graphic representation of the functioning of an amplifier transformer is given, and general equations are derived for the ratio input-voltage/output-voltage, for a large number of different circuits. The choice of the most favourable ratio is indicated for each type of circuit, and for the two classes of transformer considered—those with a more or less closed secondary circuit and those whose secondary circuit is a valve grid circuit.

ÜBER VERSTÄRKERTRANSFORMATOREN (On Amplifier Transformers).—R. Gürtler. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 58–61.)

Compares Osnos's treatment (see above) with that of Rukop (Abstracts, 1928, V. 5, p. 343) with a view to the most efficient combined use of both. The writer recommends the use of Rukop's formulæ for the preliminary design of a transformer, particularly the one proceeding from the permissible fall of the frequency curve at the limits of frequency (25 and 10^4 p.p.s.). Osnos's equations are suitable for more exact investigations, showing clearly as they do the influence of the various factors (iron-losses, leakage, etc.) in the various frequency zones.

GRID LOSSES IN POWER AMPLIFIERS.—E. S. Spitzer. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 985–1005.)

Author's summary :—In spite of the widespread use of radio-frequency power amplifiers, apparently no measurements of the power required to drive such amplifiers have ever been made. In this paper, a study of driving power is made at 60 cycles. It is found that the power input to the grid is proportional to the d-c grid current raised to the 1.34 power. The proportionality factor depends on the type of tube and the plate circuit conditions. With constant grid current the grid power input is found to be practically independent of grid bias voltage. A simple theory, based on an assumed relation between grid current and voltage, agrees quite well with the experimental results. Data are then given on six types of commercial air-cooled transmitting tubes showing driving power, a-c driving voltage, gross power output and efficiency as functions of the d-c grid current. Finally, the effects of primary and secondary electron emission by the grid on the driving power are considered.

LOW-FREQUENCY AMPLIFICATION WITH TRANSFORMERS.—P. R. Dijksterhuis and Y. B. F. J. Groeneveld. (*E.W. & W.E.*, July, 1929, V. 6, pp. 374–379.)

A theoretical investigation of the circuit shows the effect of various factors in producing imperfect reproduction. The way in which these influences are avoided in the Philips transformer type 4003 is described :—the core is made of a special nickel-iron alloy which has a much greater permeability than the usual silicon-iron core (so that for a given primary self-induction the transformer can be made one-third of the usual size) and which gives an inductance which is independent of the amplitude, whereas with silicon-iron the inductance may vary as much as from 1 to 5 according to such variation of amplitude. To keep down the resistance of the primary without risking the breaks (and consequent joints) occurring with copper wire, a special silver alloy is used having about the same specific resistance as copper but a high mechanical strength and no tendency to corrode. In the secondary, a nickel alloy wire is employed. Owing to the magnetic properties of this alloy, the secondary resistance increases very much with higher frequencies, so that the amplification keeps nearly uniform at the point (about 8–9 thousand) where there would otherwise be a leakage-resonance peak. This alloy also has good mechanical strength and no tendency to corrode. *Cf.* van Sluiters, June Abstracts, p. 326.

PUSH-PULL AMPLIFICATION : THE USE OF RESISTANCE CAPACITY COUPLING.—F. Aughtie. (*E.W. & W.E.*, June, 1929, V. 6, pp. 307–309.)

Author's summary :—To obviate the need for a transformer, use is made of the phase reversal which takes place in a single resistance capacity coupled stage, to provide a grid feed for the second valve of the output pair. A potentiometer adjustment enables the grid swings of the two output valves to be adjusted to give optimum output power, the correct setting being obtained very easily using only a milliammeter and a pair of telephones.

THEORIE DES GEKOPPELTEN SCHWINGUNGSKREISES MIT SELBSTERREGUNG (Theory of the Coupled Circuit with Self-Excitation).—Y. Watanabe. (*E.N.T.*, May, 1929, V. 6, pp. 194–210.)

The mathematical treatment used by Hecht for the theory of forced oscillations in coupled circuits is here applied to the case of the coupled circuit with self-excitation. The simplicity of the method allows it to be carried through without that neglect of certain terms which has been necessary in former investigations of the subject (*e.g.*, by Rogowski) and which—it is shown—was not always justifiable. The method is then applied to investigating the properties of the magnetically or electrically coupled intermediate-circuit valve transmitter with primary and secondary reaction. The chief results are :—a fundamental formula is obtained for the oscillation amplitude of the magnetically coupled circuit. Since the intensity of oscillation of the valve oscillator is only limited by increase of the internal resistance, the stability of both coupling-oscillations can be investigated by this formula. The critical conditions for the entry of the change-over from one frequency to the other are given by other equations. The electrostatically coupled circuit is similarly treated, and finally verification of the theoretical results is obtained by measuring the "negative admittance" and comparing with the value obtained by Appleton and van der Pol by the static method.

ÜBER DEN ZWISCHENKREISRÖHRENSENDER MIT STARK GEDÄMPFTEM SEKUNDÄRKREIS (On the Intermediate Circuit Valve Transmitter with Strongly Damped Secondary Circuit).—Y. Watanabe. (*E.N.T.*, June, 1929, V. 6, No. 6, pp. 244–248.)

A continuation of the author's investigations into this circuit published in 1925. The present paper deals with the critical value for the secondary resistance, at which the transition takes place from the second to the third type of oscillation.

ZUR THEORIE DES RÜCKGEKOPPELTEN RÖHRENSENDERS (On the Theory of the Reactively-coupled Valve Oscillator).—F. Kirschstein. (*Zeitschr. f. Hochf. Tech.*, June, 1929, V. 33, pp. 201–211.)

" A simple method of dealing with the amplitude-problem," based on characteristic curves obtained by D.C. measurements, combined with a graphical integration process. The treatment resembles Barkhausen's (" self-excitation formula ") but differs from it in dispensing with " symbolical " methods of calculation and in the introduction of a control characteristic varying with the working conditions. By this, not only can the effect of various working values on the oscillation amplitude be made particularly clear, but also a simple development of the grid " break-off " diagram is made possible.

DIE NEGADYNSCHALTUNG (The " Negadyne " Circuit).—R. H. Elsner. (*Rad., B., F., für Alle*, July, 1929, pp. 299–306.)

After remarking that this circuit was originated in Holland (Numans-Roosenstein) and that it is generally known in England as the " Newman " circuit, the writer proceeds to describe the general principles of the double-grid valve in space-charge-grid connection, and then deals with the negadyne circuit, its various forms and its uses as receiver and oscillator. The paper ends with a discussion of the literature on the subject.

RECIPROCAL THEOREMS IN RADIO COMMUNICATION.—J. R. Carson. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 952–956.)

Author's summary :—" Two reciprocal theorems, the generalised Rayleigh theorem and the Sommerfeld-Pfrang theorem are of great theoretical importance in radio-communication. A careful analysis of these theorems and their mathematical derivations shows that they are quite distinct and their practical fields of application different. In particular it shows that the Sommerfeld-Pfrang theorem labours under restrictions, implicit in its mathematical derivation, which seriously limit its field of practical applicability."

From the generalised Rayleigh reciprocal theorem deduced by the writer in 1924, however, a form may be obtained which is suitable for immediate application with the single restriction that the current (conduction plus polarisation) must be linear in the electric intensity : otherwise the medium may vary arbitrarily from point to point. This form is as follows :—If an electromotive force is inserted in the transmitting branch of antenna A_1 and the current measured in the receiving branch of A_2, then an equal current (both as regards amplitude and phase) will be received in the transmitting branch of A_1 if the same electromotive force is inserted in the receiving branch of A_2.

Here nothing is stated explicitly about power and efficiency. For the very important case, however, where the impedances of transmitter and receiver are adjusted for maximum output and maximum absorption of energy it can be shown that the ratio of the power output of the generator to the power absorbed by the receiver is the same for transmission in either direction. Thus in the case of transmission between two entirely dissimilar aerials the transmission efficiency is the same in the two directions provided the terminal impedances are properly adjusted.

It is important to note that the single restriction mentioned above implies the failure of the theorem when the waves are propagated in an ionised medium in which the earth's magnetic field has an appreciable effect on the conduction currents. This applies also to the Sommerfeld-Pfrang theorem ; so that the application of either theorem to *short wave* transmission is somewhat doubtful.

RECIPROCITY IN ELECTROMAGNETIC, MECHANICAL, ACOUSTICAL, AND INTERCONNECTED SYSTEMS.—S. Ballantine. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 929–951.)

Author's summary :—Recent criticism by Carson of the statement of the reciprocal relations in a radio communication system given by Sommerfeld is supported by a simple example showing the incorrectness of this statement.

Carson's proof of the extension of Rayleigh's reciprocity theorem to a general electromagnetic system was limited to $\mu = 1$ and to sources consisting of ponderomotive forces on the electricity. A new proof is given under more general conditions, ϵ, μ, σ being merely restricted to be scalars and the impressed forces are of the electric type introduced by Heaviside and Abraham. These may be regarded as impressed charges and currents, including ether displacement current. The theorem is finally stated in terms of volume and surface integrals, and thus combines the view-points of both Lorentz and Carson.

The reciprocity relations in a mechanical system are reviewed.

The interconnection of electrical and mechanical systems is next considered and a " transduction coefficient " is defined. This concept is useful in formulating mechanical problems in electric-circuit form. An example of symmetrical transductance (copper coil in steady magnetic field) is given. The subject of units is taken up and it is proposed that, in order to bring the mechanical quantities into agreement with the electrical ones when the latter are expressed in " practical " units, the mechanical quantities be expressed in " mechanical-volts," amperes, etc., *i.e.*, in " practical-electric units of the mechanical quantities." A table for converting the principal mechanical quantities from c.g.s. to practical-electrical units is given.

Reciprocity is shown to exist in interconnected electro-mechanical systems with reversible transduction.

The equations of sound propagation in a gas are developed, regarding the velocity and excess pressure as the fundamental quantities. An acoustical reciprocity theorem involving these quantities is then proved.

Interconnections of mechanical and acoustical systems are then discussed and reciprocal relations are shown to exist in the composite system. Such relations are also valid for a system comprising electrical, mechanical and acoustical systems in series connection.

The reciprocity relations in a reversible electrophone are applied in a method of determining the frequency characteristic of an electrophone or microphone. This is called the "method of three electrophones." The overall transmission curves of the devices taken two at a time are measured and from these data the frequency characteristic of any one of them can be calculated. Only one of the electrophones is required to be reversible.

THE MATHEMATICAL THEORY OF THE MAGNETIC FIELD ROUND A CIRCULAR CURRENT, AND ALLIED PROBLEMS.—A. Russell. (*Journ. I.E.E.*, May, 1929, V. 67, pp. 655–665.)

Author's summary:—An attempt is made to simplify the theory of the magnetic field round a plane circular current filament. The lines of force round such a filament are identical with the lines of flow round a circular vortex in hydrodynamics. A diagram showing these curves was drawn by Donald Macfarlane under Kelvin's direction in 1869 and has often been reproduced since. The author shows how the curves can be drawn by means of simple bipolar formulæ. He shows that the mutual inductance M between two concentric and coplanar circles the radii of which are a and b is given very approximately by the formula

$$M = \frac{8\pi^2 b^2}{a + 3\sqrt{(a^2 - b^2)}}$$

If b/a is less than 0.5 the maximum inaccuracy of this formula is less than 1 in 40,000. If b/a is less than 0.7 its inaccuracy is less than 4 in 1,000. It is less than 1 per cent. when $b/a = 0.9$. Even when b/a is 0.95 the inaccuracy is less than 2 per cent. A formula is given for the attraction between two coaxial circular filaments. An equation is also given from which the distance between them when their attraction is a maximum can be computed. If b is not greater than about the tenth part of a, the distance y between them, when their attraction is a maximum, is given very approximately by

$$2y = a + b.$$

In a mathematical Appendix a fairly complete list is given of formulæ for the two fundamental elliptic integrals and of formulæ for differentiating them. Some of these formulæ are new and some can only be found in treatises which are out of print and are obtainable in very few libraries. They can be usefully applied in electrical theory.

OVER HET PROBLEEM DER DEMPING IN DE MATHEMATISCHE PHYSICA (On the Problem of Damping in Mathematical Physics).—M. J. O. Strutt. (*Physica*, May, 1929, V. 9, No. 5, pp. 161–174.)

SUR LES PUISSANCES ET HORMANANCES MUTUELLES DES COURANTS ALTERNATIFS NON SINUSOIDAUX (On the Mutual Powers and "Hormanances" of Non-sinusoidal Alternating Currents).—A. Blondel. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1351–1355.)

A contribution to the discussion of the subject of power factors of non-sinusoidal A.C. The writer suggests the word "hormanance" in place of "reactive power" to represent the product of a voltage and a current displaced by 90°. For further discussion on the matter, see Iliovici, Budeanu and others in *Bull. d.l. Soc. franç. d. Élec.*, April, 1929.

THE FORCES ACTING ON CONDUCTORS SURROUNDED BY MAGNETIC SCREENS.—J. H. Morecroft and A. Turner. (*Journ. Am.I.E.E.*, January, 1929, V. 48, pp. 25–27.)

A current-carrying wire in a magnetic field has a much smaller force acting on it when it lies inside an iron tube than when it is unscreened; but if, to this smaller force, the force on the iron tube is added, the total equals the force on the unscreened wire. The paper describes experiments showing this, and showing also that each wire in a motor armature-slot contributes the same turning moment on the axle, though the wires at the bottom of the slot transmit their share direct to the core while those at the surface transmit their share by pressure on their insulating envelope.

CIRCUITS COUPLED TO TUNED AND DETUNED AERIALS.—R. Rechnitzer. (*See* two articles under "Aerials.")

UNE CURIEUSE CONSÉQUENCE DE LA RÉSONANCE D'UN CIRCUIT OSCILLANT (A Curious Result of Resonance in an Oscillating Circuit).—A. Curchod. (*Rev. Gén. de l'Élec.*, 15th June, 1929, V. 25, pp. 925–929.)

The "pumping" action of an iron armature partly entering an inductance coil which is in series with a condenser of suitable capacity, when the circuit is supplied with an alternating voltage, is here investigated.

TRANSMISSION.

REICHWEITENVERSUCHE MIT ZENTIMETERWELLEN (Range Tests with "Centimetre" Waves).—W. Ludenia. (*E.N.T.*, June, 1929, V. 6, No. 6, pp. 248–249.)

A preliminary report on experiments backed by the Telefunken Company. With a transmitter of 35 w. primary energy, a range of 3 km. was obtained with a 40 cm. wave and with a 20 cm. wave. Later (July, 1928) this was increased to 10 km. for a 40 cm. wave. For telegraphy, a simple Hertz spark oscillator was used, fed with 500 frequency A.C. For telephony a similar oscillator was fed with a frequency of 10,000 to 100,000. The calculated mean radiated energy was about 10 w. This comparatively high figure was obtained by the use of particularly favourable electrode material, by special design of dipole, by loss-free choke leading-in of the H.T., and by a multiple arrangement of dipole systems with synchronised feed.

Reception was first accomplished, with good success, with a dipole and a galena detector. Later, a triode in Barkhausen-Kurz connection was used, the triode being specially designed for short wave work and the connections being provided with choking coils. Hertzian cylindrical reflectors (dimensions $2\lambda \times \lambda$, focal length $\lambda/2$) were used at transmitter and receiver. With reflectors of focal length 2λ the radiated sector could be brought down to 6 degrees. Paraboloid reflectors also "behaved well." Wavelengths were measured by the production of stationary waves in air.

As regards propagation, only the space wave seems to be effective. Trees, hillocks, etc., act as perfect screens. The height of transmitter and receiver should be not less than 30 wavelengths above the "subterranean water mirror" (grundwasserspiegel), otherwise the range falls off rapidly. No fading or atmospherics were found, but in bright sunlight (especially over water or snow) the waves suffered a certain amount of absorption. They passed unweakened through thick fog, rain or snow-storms. No sign of rotation of the plane of polarisation could be found.

GERICHTETE TELEPHONIE MIT UNGEDÄMPFTEN 14-CM-WELLEN (Beam Telephony on 14 cm. Undamped Waves.)—K. Kohl. (*Naturwiss.*, 5th July, 1929, V. 17, p. 544.)

Long ranges with short waves can only be accomplished with waves down to about 10 m. in length; shorter waves are limited to all intents and purposes to the straight-line path between sender and receiver—as Fassbender has shown with 3 m. [3.7 m.] waves (May Abstracts, p. 264). But the shorter the waves the more do they lend themselves to directive working, and the writer finds no difficulty in generating and receiving a 14 cm. beam, using special valves made by the TKD (Nürnberg). A telephony range of 1,400 metres has been obtained, and since transmitter and receiver are exactly similar, two-way (change-over) communication is given. For purposes hitherto served by light-telephony, these "decimetre" waves seem to possess important advantages.

ÜBER DIE INTENSITÄT UND ZUSAMMENSETZUNG DER STRAHLUNG VON VERSCHIEDENEN PUNKTEN DES MASSENSTRAHLERS (On the Intensity and Composition of the Radiation from Different Points of the "Agglomerate-Radiator").—A. G. Arkadiewa. (*Zeitschr. f. Phys.*, 6th June, 1929, V. 55, No. 3/4, pp. 234–251.)

The writer's work with this apparatus on the generation of very short waves (from a fraction of a millimetre to about 50 mm.) has been known since 1923, and the first part of the present paper was read in 1926. The second part, which deals with the measurement (by means of an interferometer) of the wavelengths emitted from different points, and with the work—on the same lines—of Schardin, was read in 1928. A vertical disc rotates with its lower edge immersed in an agglomerate of metallic granules (aluminium shavings) suspended in machine oil. As the disc rotates, its edge carries with it a coating of the agglomerate; two electrodes, pointing to the centre of this coating but at a little distance from it, conduct a current through it by sparking to its surface. The main body of the oil is kept continuously stirred or "in vibration" by a rotating stirrer.

Concentration of the radiated waves is accomplished by concave metal mirrors 15 cm. in diameter and quartz lenses, and intensity measurement is carried out by a thermoelement at a resulting focus. Results are summarised as follows:—the oscillations are generated at the two points of entry of the "lead-in" sparks and also at the space between them, the greatest energy being at the points of entry. The radiated energy is independent of the nature of the metallic granules. The composition of the radiation varies for different points, the points of entry of the sparks give shorter waves than the space between, which appears to give a mixture of longer waves. The optical system described, being smaller than the one used in the early experiments, brings out the presence of shorter waves previously masked; the latest measurements are of waves going down to 0.07 mm.

EINIGE VERSUCHE MIT DEM ELEKTROLYTISCHEN GENERATOR (Some Experiments with the Electrolytic Generator).—V. M. Schulgin. (*Physik. Zeitschr.*, 15th April, 1929, V. 30, pp. 235–237.)

Continuing his work on the generation of H.F. oscillations by an electrolytic cell (January Abstracts, p. 42) the writer found that the chief generating source was the hydrogen set free at the platinum wire electrode. He therefore now uses a gas electrode as cathode. Using 240 volts, he obtains in an indoor aerial 5 m. long high-frequency currents of 0.15 to 0.4 ampere. The frequency is not actually specified.

1.7–12 METRE GENERATING CIRCUITS.—W. J. Lee. (*QST*, July, 1929, V. 13, pp. 30–31, 88.)

In the course of an article describing physiological experiments with ultra-short waves, the writer illustrates and describes the various generating circuits tried. A push-pull circuit gave good results and has been used for similar tests at the Rockefeller Institute, but the writer prefers the single-valve "Huxford" oscillator. With this circuit, using a UX-852 valve with 1,500 v. on the anode, the current induced in a tuned secondary circuit (between the plates of whose condenser the physiological effects were produced) varied from 1.5 A. for a 1.7 m. wave to 4.0 A. for a 10 m. wave.

BROADCAST POWER AMPLIFIERS.—W. T. Ditcham. (*Marconi Rev.*, May, 1929, No. 8, pp. 12–20.)

ENERGY-TRANSFER IN SHORT WAVE TRANSMITTERS. —(German Patent 473741, Telefunken, pub. 20th March, 1929.)

The separation in space of one stage from the next is desirable to avoid mutual reactions, but is difficult owing to the fact that the inductance must be kept small. An intermediate "coupling" circuit is here proposed, which may possess an electrical length equal to several wavelengths; a point of this is earthed.

FREQUENCY MODULATION.—G. H. Makey. (*E.W. & W.E.*, July, 1929, V. 6, p. 384.)

Referring to Holmblad's letter (July Abstracts, p. 390) the writer says that the conclusions are invalidated by the use of a wrong formula to represent the frequency modulation system specified in the Westinghouse patent. The correct formula cannot be split into a series of side-band terms by any method known to the writer, who however explains that he does not support the claims of the system, and suggests that others may be able to split the correct expression — $i = A \operatorname{Sin} (\omega t + kt \operatorname{Sin} mt)$—into the sum of a series of simple sine terms.

PREVENTION OF PARASITIC OSCILLATIONS IN SHORT WAVE OSCILLATORS.—(German Patent 472732, Lorenz, pub. 4th March, 1929.)

The use of ohmic resistances (socket-less incandescent lamps are recommended) in grid and anode leads is here specified.

TRANSMISSION ON TWO WAVES FOR THE ELIMINATION OF FADING.—(German Patent 472659, Esau, pub. 4th March, 1929.)

An otherwise symmetrical two-valve oscillator circuit is made to emit two different frequencies simultaneously by connecting a capacity across grid- and anode-connections at a point which is not symmetrical.

ELIMINATION OF DISTURBANCES IN H.F. GENERATORS.—(German Patent 474373, Lorenz, pub. 5th April, 1929.)

Disturbances (*e.g.*, "trill effects") due to the slight eccentricity of the rotor are here neutralised by inserting in the H.F. lead an iron-cored choke with polarising and auxiliary windings, the latter being fed with carefully adjusted current impulses in time with the disturbances (*e.g.*, by tapping diametrically-opposed points on the armature of the D.C. motor driving the alternator).

CONTROL OF IDLE LOAD IN VALVE KEYING.—(French Patent 651720, Telefunken, pub. 27th Feb., 1929.)

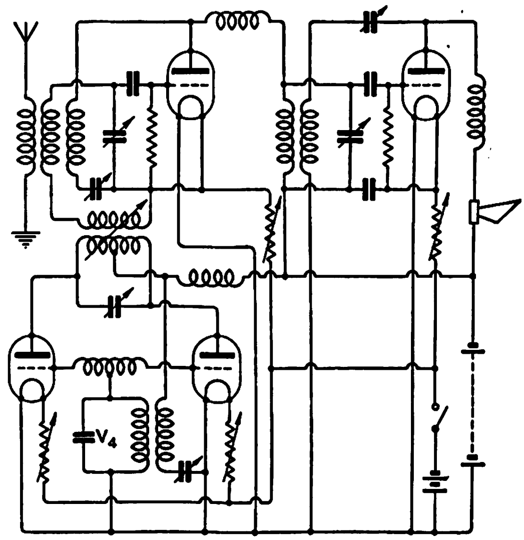
This particular method includes a rectifier valve in a circuit coupled to the generator valve oscillating circuit. The rectifier circuit (which includes a condenser shunted by a resistance) is connected to the grid of the idle-load valve, whose grid bias is thus affected by the strength of the oscillating current. *Cf.* Telefunken patent, August Abstracts.

RECEPTION.

RECHTECKIGE VERFORMUNG VON RESONANZKURVEN NACH EINEM NEUEN PRINZIP, UND IHRE ANWENDUNG BEIM EMPFANG SEHR KURZER WELLEN (The Rectangular Formation of Resonance Curves on a New Principle, and its Use in the Reception of Very Short Waves).—H. E. Kallmann. (*Zeitschr. f. Hochf. Tech.*, June, 1929, V. 33, pp. 212–223.)

Author's summary :—"Undesired frequency fluctuations in work with very short waves demand, just as telephonic modulation demands, a decrease of receiver selectivity. At present, this decrease is usually brought about by higher damping in the receiver oscillating circuit; but the consequent gradual slope of the damped resonance curve is very undesirable because of the increased liability to interference. For the formation of an approximately rectangular curve of receiver sensitivity, it is here proposed to vary one of the natural frequencies involved over a narrow range at supersonic periodicity, so that the frequency band swept over is broader than the sum of all the [transmitter] fluctuations. . . ."

In practice it would be undesirable to vary the transmitter frequency, and equally undesirable to use some mechanical method of varying the natural



frequency of the receiver circuits. The true application of the method lies therefore in heterodyne reception, the heterodyne generator frequency being varied at supersonic frequency by a method depending on the variation of grid resistance or grid bias. In the actual tests, with a push-pull oscillator (using one double valve) it was found that an A.C. grid voltage of 1 v. was enough to produce the desired effect, and one arrangement successfully employed consisted in connecting a circuit of suitable wavelength in the lead to the grids, with reactive coupling to the anode circuit.

The diagram shows such a local oscillator, of periodically varying frequency, combined with the receiver for which it provides the heterodyne frequency. V_4 represents the frequency-varying circuit. The wavelengths used in all the tests were of the order of $2\frac{1}{2}$ metres.

ON HETERODYNE RECEPTION.—I. Tanimura. (*Electrot. Lab. Tokyo*, Circular No. 58, April, 1929.)

In Japanese. The theories of Hogan, Liebowitz, Howe, Appleton and Taylor are discussed, and some experimental results obtained by the writer

are shown, which serve to verify the theory of Appleton and Taylor.

Receiver with Aperiodic High-frequency Amplification.—M. v. Ardenne. (*E.W. & W.E.*, July, 1929, V. 6, pp. 369–373.)

After discussing the advantages of the aperiodic amplifier with resistance coupling over the tuned-high-frequency amplifier (simplicity, cheapness, and reduced anode current) the writer deals with the construction and employment of the new multiple valve developed by himself and Loewe (2 H.F., single grid only) for a cascade of such amplifiers. *Cf.* same author, April Abstracts, p. 210.

Un Régulateur Anti-fading (An Anti-Fading Regulator).—L. Chrétien. (*T.S.F. Moderne*, April, 1929, V. 10, pp. 201–213.)

In a frequency-changing receiver, the variable P.D. produced by the fading is used to control the amplification of the intermediate-frequency stages. Unlike de Bellescize (who uses a relay), the writer applies the variable P.D. directly across a resistance in the grid-bias battery circuit, so that it adds to or subtracts from the bias of the intermediate-frequency valves. Curves showing practical results are given.

Reducing Noise in Broadcast Receivers.—R. Wm. Tanner. (*Rad. Engineering*, March, 1929, V. 9, pp. 24–25.)

"Noise" here includes atmospherics, interference from power lines and from nearby wireless stations. The article deals chiefly with the revival of the 1920 "resonance wave coil" in which the aerial is connected to a long helix, the top third of which is surrounded by a closely-fitting metal tube connected to earth through a rejector circuit. The receiver connection is taken from a shorter, split tube sliding over the remaining part of the helix. Results with this device cannot be quite satisfactory when battery eliminators are used unless these are provided with electrostatic shields between primaries and secondaries, to prevent the aerial effect of the supply line.

The use of band-pass filters (for superheterodyne receivers) is dealt with briefly, and the paper ends with a paragraph on the reduction of hum in A.C.-fed receivers by reducing the audio-amplification to one stage—by using a "power" detector valve working direct to the power amplifying valve.

Amplifier Noises: Setting a Limit to Long-Distance Frame-Aerial Reception.—A. L. M. Sowerby. (*Wireless World*, 24th July, 1929, V. 25, pp. 75–78.)

Atmospheric Elimination. (German Patent 466030, Telefunken.)

Two intermediate, aperiodic circuits, taking their energy from two separate coils in the same aerial, act in an opposed sense on a third circuit. One of the aperiodic circuits is coupled to a rejector circuit tuned to the in-coming wave.

Registrierung von radiogegebenen Zeichen (Recording Wireless Signals).—B. Brockamp. (*Zeitschr. f. Geophys.*, No. 7/8, 1928, V. 4, pp. 404–405.)

Description of an apparatus, suitable for field work, which records very quick signals and notes of very different frequencies, giving sharp beginning and break-off.

Some Uses for the Neutralising Condenser.—(*Wireless World*, 22nd May, 1929, V. 24, p. 532.)

Some suggested unorthodox applications for the neutralising condenser in H.F. circuits are:—(1) as variable coupling between two tuned circuits; (2) as the reaction control in a Hartley circuit where the tuning-coil has a centre-tap; (3) for matching various tuning condensers in two or more tuned receiving circuits. In this latter case a neutralising condenser connected in parallel with each of the remaining circuits will compensate for the minimum capacity in the aerial circuit being higher than elsewhere.

AERIALS AND AERIAL SYSTEMS.

Die abgestimmte, induktiv gekoppelte Antenne (The Tuned, Inductively Coupled Aerial).—R. Rechnitzer. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 62–75.)

Some of the results of this theoretical investigation are as follows:—amplification without reaction has an optimum when $K = \sqrt{d_A d_g}$ (where K is the coupling factor and d_A and d_g are the decrements of the aerial and of the grid circuit). The actual value of maximum amplification is

$$V_{\max.} = \frac{1}{2d_g}\sqrt{\frac{R_g}{R_A}}.$$

The selectivity of the arrangement is given by

$$S = \frac{a^2}{d_A d_g(1 + a^2)}, \text{ where } a = \frac{K}{K_{\text{opt.}}} \text{ and } \alpha = \frac{1}{x} - x,$$

x being the ratio representing the detuning. For a good compromise between selectivity and strength of signal, a may be 0.5 to 0.7.

The Effect of the Earth on Short-Wave Radiation from Vertical and Horizontal Aerials.—G.W.O.H. (*E.W. & W.E.*, July, 1929, V. 6, pp. 351–352.)

An editorial note on our more recent knowledge of the subject, and its progress since the nearly twenty-year-old Sommerfeld theory of the radiation from a vertical aerial. Particular attention is given to Strutt's paper (June Abstracts, p. 329): "Perhaps the most important result of the investigation is that the usefully radiated energy of a horizontal antenna, if placed at a proper height, is not less than that from a similar vertical antenna, which agrees with the results of long-distance measurements with both types of aerials."

A Reflector System.—(German Patent 460270, Galletti).

The wires forming the reflector are disposed along a closed ellipse so as to form a cylinder of

elliptical cross section, which has a radiating antenna at one or both foci, and which is closed at one end; the radiation takes place in the direction of the open end.

Die Selektivität eines mit einer verstimmten Antenne gekoppelten Empfangskreises (The Selectivity of a Receiving Circuit Coupled to a Detuned Aerial).—R. Rechnitzer. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 75–80.)

The writer quotes the work of Zepler (*ibid.*, No. 44, December, 1926) where the theory of one form of this circuit, the conditions for obtaining a good selectivity, and the calculation of the amplification are all gone into. The present paper investigates the increased selectivity of a more complex form of the circuit, in which not only the coupling is variable but also the aerial circuit, which now contains a variable series condenser.

Short Wave Aerial in High Vacuum.—(German Patent 461142, O. Muck.)

The object of enclosing the aerial in a vacuum is to avoid corona.

Directive Aerial System.—(German Patent 474123, Hahnemann, published 27th March, 1929.)

This is a 1924 patent, according to which the best sharpness of beam is obtained by spacing the n aerials so that the distance apart $d = \frac{n-1}{n} \cdot \lambda$.

Influence of Weather Conditions on British Overhead Lines.—G. W. Molle. (Summary in *Science Abstracts*, Sec. B., 25th May, 1929, V. 32, pp. 297–298.)

Feeding of an Extra-high Frequency Power through a Metallic Pipe.—E. Takagishi, E. Iso, and S. Kawazoe. (*Res. Electrot. Lab. Tokyo*, No. 245, January, 1929.)

In Japanese. Two specimens of "beam transmission" feeder systems were tested, one being a copper conductor with a concentric copper pipe, and the other a similar copper conductor with a galvanised iron pipe. Transmission efficiencies (for feeder 55 m. long) were nearly 86 and 82 per cent. respectively.

Short Wave Receiving Aerials.—(French Patent 648548, Radio Corp., published 11th December, 1928.)

To make the propagation velocity in the wires of a Beverage aerial equal to that in space, a number of horizontal wires of length equal to half the wavelength are attached or capacitively coupled to the long horizontal wires.

VALVES AND THERMIONICS.

Further Remarks concerning Thermionic "A" and "b"; a Revision and Extension.—E. W. Hall. (*Proc. Nat. Acad. Sci.*, June, 1929, V. 15, pp. 504–514.)

The work of Du Bridge and Warner and of Bridgman may seem highly unfavourable to the writer's thesis that electric conduction in metals is carried on by electrons in two different states, the "free" electrons or "thermions" which are the ones issuing in thermionic emission, and the "associated" or "valence" electrons which are the ones expelled in photoelectric action. The writer, however, here undertakes to show that all this evidence, both experimental and thermodynamical, is entirely consistent with his thesis.

Contact Potential Measurements with Adsorbed Films.—I. Langmuir and K. H. Kingdon. (*Phys. Review*, 1st July, 1929, V. 34, pp. 129–135.)

The values obtained do not agree with those calculated from the thermionic emission constants.

Thermionic Emission Associated with Electrons belonging to Atoms, not with Free Electrons?—(*See* Ives and Olpin, under "Phototelegraphy.")

Die experimentelle Prüfung des Maxwellschen Geschwindigkeitsverteilungsgesetzes für Elektronen, die aus einer Glühkathode austreten (The Experimental Verification of Maxwell's Law of the Distribution of Velocities for Electrons Emitted by a Hot Cathode).—A. Demski. (*Physik. Zeitschr.*, 15th May, 1929, V. 30, No. 10, pp. 291–314.)

The Interaction of Electron and Positive Ion Space Charges in Cathode Sheaths.—I. Langmuir. (*Phys. Review*, June, 1929, V. 33, pp. 954–989.)

Jaffe's theory rejected: the Theory of the Effect of Ions on Space Charge Currents between Parallel Planes: Potential Distribution and Current Flow resulting from the Production of Ions uniformly throughout the Volume between two Planes: Effect of the Electrons generated by Ionisation: Random Currents and Potential Distribution in the Plasma: Theory of Double-Sheath considering Initial Velocities: the Sheath Edge: Experimental Data on Double Sheaths: Tube with Oxide Coated Cylindrical Cathode: Filamentary Cathodes.

The Rectification of Radio Signals by a Thermionic Tube containing Alkali Metal Vapor.—K. H. Kingdon and E. E. Charlton. (*Phys. Review*, June, 1929, V. 33, pp. 998–1018.)

Authors' abstract:—The cathode of a thermionic triode tube is surrounded by a region of minimum potential caused by electron space-charge. If the cathode is of thoriated tungsten, and the tube contains cæsium vapor, a few positive ions are formed by ionisation of cæsium atoms striking the hot cathode. Some of these ions accumulate around the potential minimum, raise the potential at that point, and allow a larger electron current to flow to the anode. The ions have a natural frequency of oscillation about the potential minimum, which is usually several hundred kilocycles. If an alternating voltage is applied to the tube, of a frequency agreeing with

this natural frequency, the ions are set in oscillation about the potential minimum. This oscillation of the ions makes the potential minimum more negative, and decreases the anode current. In addition the amplitude of oscillation may build up by a resonance effect to such a large value that the ions are able to discharge to one of the neighbouring conductors, leading to a still greater decrease in anode current. This kind of rectification is much greater for small alternating voltages than that resulting from curvature of the triode characteristics.

MOTION OF POSITIVE IONS IN A PLASMA.—L. Tonks and I. Langmuir. (*Phys. Review*, June, 1929, V. 33, p. 1070.)

Hitherto it has been assumed that positive ions in a plasma have a " temperature " about one-half the electron temperature, to account for the positive ion currents which flow to electrodes and walls. This assumption causes theoretical difficulties which are overcome by supposing that each new positive ion has the small temperature of a gas atom and accelerates only under the influence of fields arising from the tendency of the high temperature electrons to flow away.

FURTHER STUDIES IN THE EMISSION OF ELECTRONS FROM COLD METALS.—T. E. Stern, B. S. Gossling and R. H. Fowler. (*Proc. Roy. Soc.*, 1st July, 1929, V. 124 A, pp. 699–723.)

An examination of the space charge effect and of the effect of surface films on the emission coefficient, leading also to an explanation of the fugitive temperature effect. The paper begins by an important correction of a numerical mistake in an exponential factor in Fowler and Nordheim's original paper.

DIE THEORIE DER ELEKTRONENEMISSION DER METALLE. ZUSAMMENFASSENDER BERICHT (The Theory of Electron Emission from Metals: a Survey).—L. Nordheim. (*Physik. Zeitschr.*, 1st April, 1929, V. 30, No. 7, pp. 177–196.)

MATHEMATICAL THEORY OF THE FOUR-ELECTRODE TUBE.—J. G. Brainerd. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1006–1020.)

The work is essentially an extension to the four-electrode valve of Carson and Llewellyn's work on the triode. Author's summary :—" This paper gives the mathematics of the four-electrode tube, including in the most general case expressions for the plate and two grid currents in terms of applied voltages in the two grid circuits and the impedances of all three circuits. The results are exact, variation in the amplification factors being included. Because of the complexity of the general equations, these expressions for the currents have been developed: I, in terms of one grid-filament voltage and external impedances in plate and other grid circuit, assuming no voltage in latter; II, in terms of grid-filament voltages of both grid circuits and external impedance in plate circuit; III, in terms of applied voltages in both grid circuits and external impedances in plate and two grid circuits.

" The results of I show the effect of an external impedance in the non-control grid of a ' screen-grid ' or ' space-charge-grid ' tube; II covers the approximate theory of a ' double-function ' tube; III gives a more exact and comprehensive theory of the tube in any use."

MEASUREMENTS OF ELECTRICAL FLUCTUATION PHENOMENA.—H. A. Wheeler. (*Phys. Review*, January, 1929, V. 33, p. 124.)

Investigations of shot effect, flicker effect and thermal convection in conductors by a method which amplifies the variations and uses them to obtain galvanometer deflections without previous rectification.

HOT CATHODE THYRATRONS: PART II: OPERATION.—A. W. Hull. (*Gen. Elec. Review*, July, 1929, V. 32, pp. 390–399.)

Second and final part of the paper referred to in June Abstracts, p. 330 (*see* also Hull and Langmuir, same page). Various applications are described and the suitable circuits illustrated, *e.g.*:—in connection with photoelectric cells; a circuit for measuring the maximum value of a transient; as an " inverter " for converting D.C. into A.C. By the use of a sensitive rheostat (a pile of thin carbon discs, in series with a resistance and a source of A.C. voltage, the voltage across the resistance being applied to the thyratron grid) a displacement of 1/100,000 inch will start the thyratron, releasing a current of many amperes.

UNE NOUVELLE LAMPE DE PUISSANCE: LA LAMPE " PHILIPS " MINIWATT B.443 (A New Power Amplifier Valve: the Philips Miniwatt B.443).—A. van Sluiters. (*Rev. Gén. de l'Élec.*, 8th June, 1929, V. 25, pp. 901–904.)

After pointing out that with power valves with only one grid the amplification is reduced by the action of the anode on the anode current, the writer shows how the three-grid valve named avoids this trouble; his calculations show that a second grid quadruples the power; the third grid (next the anode) is kept at filament potential so that whatever polarity changes the second grid may undergo, the secondary electrons set free at the anode will return to the anode.

GRID LOSSES IN POWER AMPLIFIERS.—E. S. Spitzer. (*See under* " Properties of Circuits.")

THE MODERN H.F. VALVE: SINGLE STAGE AMPLIFICATION OF TWO OR THREE HUNDRED WITH THE NEW SCREEN-GRID VALVE.—W. I. G. Page. (*Wireless World*, 24th and 31th July, 1929, V. 25, pp. 68–71 and 107–110.)

" It is the purpose of these notes to examine the relative merits of some twenty typical H.F. valves with a view to finding the maximum stage amplification which can conveniently be obtained with them." Among other points:—there are at least two screened valves now available which have anode-grid capacities as small as that in Hull's experimental valve (0.006 $\mu\mu$F.). The regaining of

selectivity by using a step-up transformer in place of the 1 : 1 transformer (which is about the best for a screen-grid valve) is discussed, and it is concluded that the consequent loss of amplification is not enough to reduce that type of valve to the level of the cheaper triode.

VALVE SELECTING CHARTS: A NEW CLASSIFICATION OF RECEIVING VALVES.—R. T. Beatty. (*Wireless World*, 17th July, 1929, V. 25, pp. 48–52.)

DIRECTIONAL WIRELESS.

RADIO DEVELOPMENTS APPLIED TO AIRCRAFT.—J. H. Dellinger and H. Diamond. (*Mech. Engineering*, July, 1929, V. 51, pp. 509–514.)

An article chiefly on the "equi-signal" beacons referred to in several past Abstracts. A section on fog landing discusses briefly the various types of altimeters: it is mentioned that the one depending on capacity-change ("the change in capacity between two plates on the airplane as the airplane approaches the ground") suffers from the limitation that at altitudes above 100 ft. the change in capacity is infinitesimal.

ACOUSTICS AND AUDIO-FREQUENCIES.

DER HEULSUMMER UND SEINE VERWENDUNG BEI RAUMAKUSTISCHEN MESSUNGEN (The "Howling" Hummer and its Use in the Measurement of Room-Acoustics).—P. Just. (*Schalltech.*, No. 1, 1929, V. 2, pp. 5–9.)

The conversion of the ordinary glow-lamp hummer or the heterodyne hummer into a "howling" hummer, by means of a continuously rotating condenser, gives an arrangement very useful for intensity measurements in rooms, as it gets rid of interference effects. Oscillograph echo curves are given showing the success obtained.

MEASUREMENTS ON SOUND DAMPING MATERIALS.—E. Meyer and P. Just. (*T.F.T.*, February, 1929, V. 18, pp. 40–45.)

The method described depends on the measurement of the time at which echoes occur after the suppression of the sound.

THE MOVING COIL LOUD SPEAKER.—H. M. Clarke. (*E.W. & W.E.*, July, 1929, V. 6, pp. 380–384.)

A method is described of obtaining a "constant impedance non-inductive instrument which lends itself to damping by suitable filter circuits" (thus avoiding resonance-effects), "which allows of the use of the maximum power output available, and which may be controlled externally to obtain any required response characteristic."

The method is a compensating-winding method: a coil on the inner pole contains half as many turns as the moving coil, and a similar coil is fixed to the outer pole in the air-gap outside the moving coil. The latter is thus evenly flanked by as many fixed turns as it contains itself, the fixed windings being in series in such a way that they magnetically oppose the moving coil. Hysteresis, eddy currents and self-induction can thus be reduced to a negligible quantity. The use of such an instrument with suitable damping circuits is investigated; apart from the production of practically any response curve desired, the improvement of power factor facilitates the rise of current to its full value, while the shunting circuit cuts down the time during which transients are maintained.

THE ACOUSTIC PERFORMANCE OF A VIBRATING RIGID DISK DRIVEN BY A COIL SITUATED IN A RADIAL MAGNETIC FIELD.—N. W. McLachlan. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 1011–1038.)

Author's summary:—The object of this paper is to examine analytically the performance of an arrangement akin to the type of loud speaker used for acoustic reproduction in which the driving agent is a circular coil situated in a strong radial magnetic field.

Accordingly the paper deals with the acoustic performance of a rigid disk, supported at its periphery and driven by a concentric circular coil situated in a radial magnetic field of constant value. Alternating current passed through the coil (which is connected in the anode circuit of a thermionic valve) causes the disk to vibrate axially. The simultaneous differential equations associated with the mechanical and electrical aspects of the problem are solved for the steady and the transient state, with and without elastic constraint at the periphery. Expressions are obtained for the acoustic radiation resistance, the acoustic power radiated, and the current in the moving coil. It is shown that the E.M.F. induced in the coil, due to its motion in the magnetic field, is concomitant with a capacity reactance in quadrature with the acoustic radiation resistance. By virtue of this and the inductance of the coil, the system has an electromechanical resonance frequency. If the damping is adequately small the mechanical system will execute oscillations in the absence of elastic constraint. Electrical circuit diagrams equivalent to the mechanical and electrical systems combined are given for the constrained and unconstrained conditions of the disk. These facilitate the study of transients.

The analysis is illustrated by curves showing the coil current, acoustic output, and axial pressure for three different disks. It is shown that, under set conditions, there is a certain size of disk for which the output is a maximum. A curve is also given by the aid of which the accession to inertia due to the divergence of the waves propagated by the disk can be evaluated.

MOVING COIL LOUD SPEAKERS, WITH PARTICULAR REFERENCE TO THE FREE-EDGE CONE TYPE.—C. R. Cosens. (*E.W. & W.E.*, July, 1929, V. 6, pp. 353–368.)

"Although loud speakers in general are not suitable for simple mathematical treatment, it so happens that the 'moving-coil free-edge cone' is amenable to analysis if we make certain simplifying assumptions; and the results so obtained appear to resemble the results of experiment sufficiently closely to be of value for design purposes." Rayleigh's definition of the "intensity" of sound

at a point is used to derive (by integration over a closed surface) a measure of the "output" or volume W. By making two of the above-mentioned assumptions, it is shown that if E_g is the R.M.S. value of the E.M.F. applied to the grid of the receiver power stage, faithful reproduction of the sound in the studio demands that $W \propto E_g^2$ throughout the important frequency-range. Other assumptions made are that the diaphragm is perfectly plane and rigid, with an infinite plane baffle (so that Rayleigh's investigation of such a diaphragm can be used) and that there is no energy-loss in the suspension.

The formulæ arrived at are later applied to the design of a particular loud speaker. Among the various points in design which emerge is the fact that for the sake of the higher frequencies, the coil inductance must be kept down—*i.e.*, the minimum of wire on as large a diameter as possible should be used—so that McLachlan's 2 in. diameter coil should be better from a high-note point of view than the ¾ in. coils of commercial types. Regarding this high-note reproduction, the writer shows that it is accomplished through resonant vibrations of the diaphragm of which his calculations take no account (since they assume a perfect rigidity) so that his equations really apply to the lower frequencies only. Various plans for increasing the high-note reproduction are discussed, but the writer concludes that the elastic vibrations of the diaphragm itself are enough for the purpose—in fact, the use of a stiff varnished paper for the cone sometimes appears to overdo it and to give too much high frequency.

SOUND RADIATION FROM A SYSTEM OF VIBRATING CIRCULAR DIAPHRAGMS.—I. Wolff and L. Malter. (*Phys. Review*, June, 1929, V. 33, pp. 1061–1065.)

" . . . At low frequencies the diaphragms react upon each other to increase the efficiency of radiation. This effect vanishes at high frequencies. . . . In certain cases the combination may result in decreased efficiency over particular frequency ranges. These results are all explainable on the basis of phase differences between motion of a diaphragm and the pressure over the surface of another diaphragm due to the motion of the first."

THE "BREAKING-UP" OF LOUD SPEAKER DIAPHRAGMS.—N. W. McLachlan. (*Wireless World*, 10th and 17th July, 1929, V. 25, pp. 33–35 and 62–64.)

An analysis of the modes of vibration of the diaphragm: how nodal points are traced by means of dust patterns.

THE KYLE CONDENSER REPRODUCER.—C. Kyle. (*Rad. Engineering*, March, 1929, V. 9, pp. 26–29.)

Practical and theoretical discussion of a new electrostatic loud speaker which has a perforated back-plate with "corrugations or other undulated surface," a flexible dielectric diaphragm stretched over this back-plate so as to bridge across the depressions, and a thin flexible conducting coating cemented or otherwise fixed to the inner surface of the diaphragm. The wedge-shaped air spaces thus obtained are said to give a good compromise between sensitivity and good frequency-response.

SILVER SOLDERS IN RADIO LOUD-SPEAKERS.—R. R. Shuman. (*Rad. Engineering*, March, 1929, V. 9, p. 40.)

For the joint between suspension spring and silicon steel armature, soft solder disintegrates under the vibration and hard (or spelter) solder requires too high a temperature. Silver solders are found to be satisfactory.

PHOTOTELEGRAPHY AND TELEVISION.

BILDTELEGRAPHENBETRIEB ÜBER LEITUNGEN (Picture Telegraphy Service over Conductors).—P. Arendt. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 30–39.)

An article on the various services on which the Telefunken-Karolus-Siemens system is used, including the Japanese overhead line and cable network and the England-Scotland-Paris-Berlin press network.

BILDFUNK MOSKAU-BERLIN (Moscow-Berlin Picture Telegraphy).—P. W. Schmakow. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 5–29.)

A detailed and profusely illustrated description of the Telefunken-Karolus system used on this wireless service, and of the tests leading to the successful establishment of communication at the end of 1927. Improvements since that time are only briefly mentioned: *e.g.*, the problem of rendering the Kerr cell controllable by smaller voltages by reducing the gap, without thereby reducing the amount of light passed, was solved by the use of a number of small gaps forming a "multi-cell."

TELEVISION BY THE MIHÁLY SYSTEM: FIRST DESCRIPTION OF A NEW RECEIVER SHORTLY TO BE SEEN IN THIS COUNTRY. (*Wireless World*, 3rd July, 1929, V. 25, pp. 7–9.)

RECEIVING SYSTEM FOR PICTURE TELEGRAPHY. (German Patent 474371, Iszerstedt, pub. 2nd April, 1929.)

Elements of light and shade are produced by the movements of pins with black heads in a white liquid or with white heads in a black liquid, these movements (regulated by electromagnets) bringing the heads right up to, or taking them away from, the surface of the liquid in which they are immersed. In practice the "surface" would presumably be the bounding wall of a transparent container.

PHOTORADIO DEVELOPMENTS.—R. H. Ranger. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 966–984.)

The first part of the paper deals briefly with general developments 1926–1928, including the work of Karolus, Schriever, G. M. Wright, Jenkins and Dieckmann (simple equipments for recording weather maps), Thorne-Baker, Cooley (amateur

apparatus recording by corona discharge on photographic paper) and Korn. A fundamental improvement is the use of the dot-dash method of representing picture values instead of depending on signal intensity.

The rest of the paper deals with the recent work of the Radio Corporation of America. Points mentioned are:—the advantage of making gear-ratios even (an odd ratio makes the teeth mesh in a given sequence for one line and in an entirely different sequence for the next); the use of the Push-Pull principle to reduce the inertia of relays; the elimination of reversing clutches by the use of the Reverse Lead Screw; air speed control (air-driven tuning forks working air brakes on the motor; Braman and Nelson's air drive making use of both phase and amplitude of resonance and thus providing a curve of response with a very steep portion); and hot air recording, in which a controlled stream of hot air acts on paper sensitised with chemical salts capable of undergoing an endothermic double decomposition reaction, with the formation of brownish-black products.

PICTURE TRANSMISSION FROM ORIGINALS OF VARYING THICKNESS. (German Patent 473331, Lorenz, pub. 14th March, 1929.)

When such things as manuscripts with stuck-on photographs are being transmitted, the focus may be upset: this is avoided by a pilot-wheel running over the original and regulating, by levers, the position of the lens system.

LIGHT CONTROL. (German Patent 473772, Telefunken, pub. 2nd April, 1929.)

A transparent body is immersed in a transparent medium of "almost" the same refractive index, and a ray of light passed through body and medium. If the indices of refraction are equal, the ray passes straight through without disturbance; if now the control current alters the index of the body, or of the medium, or of both [presumably in opposite senses], almost all the light is blocked out by diffuse reflection and refraction.

HIGH FREQUENCY SUPPLY FOR KERR CELL. (German Patent 473650, Telefunken, pub. 21st March, 1929.)

To avoid difficulties due to the appreciable and varying conductivity of the cell liquid, high frequency potentials are here used: the signals influence, through a modulating valve, an oscillator generating a frequency of 10^6 or more cycles per sec., which is impressed on the Kerr cell.

ÜBER DIE GESETZMÄSSIGKEITEN DER LICHTELEKTRISCHEN GESAMTEMISSION (The Conformity to Law of the Total Photoelectric Emission).—R. Suhrmann. (*Zeitschr. f. Phys.*, 21st March, 1929, V. 54, No. 1/2, pp. 99–107.)

VARIATION OF THE PHOTOELECTRIC EFFECT WITH TEMPERATURE, AND DETERMINATION OF THE LONG WAVE-LENGTH LIMIT FOR TUNGSTEN.—A. H. Warner. (*Phys. Review*, May, 1929, V. 33, pp. 815–818.)

ÜBER DAS LEITVERMÖGEN VON STARKEN ELEKTROLYTEN FÜR HOCHFREQUENZSTRÖME (The Conductivity of Strong Electrolytes for H.F. Currents).—H. Zahn. (*Zeitschr. f. Phys.*, No. 5/6, 1928, V. 51, pp. 350–354.)

Experimental confirmation of Debye and Falkenhagen's deduction that the conductivity must be greater for high than for low frequencies.

TALBOT'S LAW IN PHOTOELECTRIC CELLS.—N. Campbell. (*Phil. Mag.*, July, 1929, V. 8, No. 48, pp. 63–64.)

A criticism of Carruthers and Harrison's paper (July Abstracts, p. 395). A reply from Harrison and Stiles follows.

SUR LA THÉORIE DE L'EFFET PHOTO-ÉLECTRIQUE (On the Theory of the Photoelectric Effect).—P. Auger. (*Comptes Rendus*, 13th May, 1929, V. 188, pp. 1287–1289.)

A paper on the distribution in space of the initial directions of the photo-electrons.

ÜBER DIE HÖCHSTGESCHWINDIGKEIT LICHTELEKTRISCHER ELEKTRONEN IM SELEKTIVEN EMFINDLICHKEITSBEREICH DES KALIUMS (On the Maximum Velocity of Photoelectric Electrons in the Zone of Selective Sensitivity of Potassium).—H. Teichmann. (*Ann. der Phys.*, 7th May, 1929, 5th Series, V. 1, No. 8, pp. 1069–1095.)

PHOTOELECTRIC EFFECT AT LOW TEMPERATURES.—J. C. McLennan, L. A. Matheson and C. D. Niven. (Summary in *Science Abstracts*, Sec. A., 25th May, 1929, V. 32, p. 460.)

THE PHOTO-E.M.F. IN SELENIUM.—R. L. Hanson. (*Journ. Opt. Soc. Am.*, May, 1929, V. 18, pp. 370–382.)

The photo-E.M.F. in a selenium cell over a wide range is found to be independent of the current through the cell and bears a linear relation to the intensity of illumination. The response appears to be practically instantaneous, whereas there often seems to be considerable lag in the change in conductivity caused by illumination. The photo-E.M.F. sensitivity has a maximum for the visible spectrum in the region $\lambda = 490\ m\mu$. The effect is definitely not a thermal one. No direct relation between it and the photoelectrical conductivity was traced. Many points of agreement were found with Coblentz' "actinoelectric" effect in molybdenite.

SUR LES COURBES CARACTÉRISTIQUES DES CELLULES PHOTOÉLECTRIQUES (Photoelectric Cell Characteristics).—L. Dunoyer. (*Bull. de la Soc. franç. de Phys.*, 3rd May, 1929, No. 278, pp. 89S–90S.)

In the course of this paper, which deals largely with Campbell's work, a new type of cell is described in which the alkali metal is deposited in a thin film on the inner surface of a hemisphere closed by a transparent plate: the anode is a wire close to this plate. Above a certain voltage the current increases suddenly to a value of the same order as that

reached in ordinary cells at the inset of the disruptive régime; only in the present case the large current ceases with the illumination. As the voltage is increased, the current increases more slowly, till the voltage for the disruptive condition is reached; but between these two voltages there is a range of about 20 v. in which perfectly stable and remarkably intense photoelectric currents can be obtained. Thus a cell 4 cm. in diameter, illuminated by a carbon filament 50 c.p. lamp at 25 cm. distance will give a current up to 100 microamperes—and therefore can work a relay directly.

MAXIMUM EXCURSION OF THE PHOTOELECTRIC LONG WAVE LIMIT OF THE ALKALI METALS. —H. E. Ives and A. R. Olpin. (*Phys. Review*, 1st July, 1929, V. 34, pp. 117–128.)

Authors' abstract:—Earlier experiments have shown that the long wave limit of photoelectric action in the case of thin films of the alkali metals varies with the thickness of the film. A maximum value is attained greater than that for the metal in bulk, which for the majority of the alkali metals lies in the infra-red. The wavelength of the maximum excursion of the long wave limit was first studied for *Na, K, Rb* and *Cs*. In each case it was found to coincide with the first line of the principal series, *i.e.*, the resonance potential. If this relation holds for lithium, its maximum long wave limit should be greater than that of sodium. This was tested and confirmed by experiments in which red-sensitive lithium cells were prepared, sensitive to 0.6708 μ. It is suggested that photoelectric emission is caused when sufficient energy is given to the atom, to produce its first stage of excitation. The identity of photoelectric and thermionic work functions suggests that atomic excitation is the initial process in thermionic emission as well.

LIGHT-SENSITIVE CELLS. I.—CONSTRUCTION OF ALKALI METAL CELLS.—J. P. Arnold. (*Rad. Engineering*, March, 1929, V. 9, pp. 21–24.)

The first of a series of four articles dealing with design, development and application of all representative types of light-sensitive cells.

MEASUREMENTS AND STANDARDS.

THE MEASUREMENT OF DIRECT INTERELECTRODE CAPACITANCE OF VACUUM TUBES.—A. V. Loughren and H. W. Parker. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 957–965.)

Authors' summary:—"A method of measuring direct capacitance in the range 10^{-10} to 10^{-15} farad by a charging current at radio frequencies is described. A low resistance current indicator is shunted across one of the direct capacitances. The charging current $I = \omega EC$ is a measure of the direct capacitance provided that ωE is maintained constant. A simple circuit arrangement provides an apparatus giving reliable results measured visually by substitution with a standard.

The method has been practically applied in the measurement of direct capacitances present in vacuum tubes providing data for design purposes and for control of product uniformity. The method is specially advantageous in its ability to measure exceedingly small direct capacitances present in screen-grid tubes."

The method of substitution employed eliminates the need of measuring the absolute value of the current and thus there is no need for calibration of the current indicator. The constancy of the calibration of the standard condenser is all that is required, and the use of coaxial cylinders makes this easily possible. A type shown has a capacity increase of 1.00×10^{-14} farad per turn of micrometer head.

DER GEBRAUCH VON VERSTÄRKERRÖHREN ZUR MESSUNG KLEINER ENERGIEBETRÄGE (The Use of Amplifier Valves for the Measurement of Small Amounts of Energy).—J. Brentano. (*Zeitschr. f. Phys.*, 27th April, 1929, V. 54, No. 7/8, pp. 571–581.)

The writer discusses various bridge-methods evolved by himself for the measurement of very small D.C. currents and potential differences, in which disturbance from external sources is avoided. The work of Müller and Frisch and of Wynn Williams in the same field is referred to and criticised (*cf.* Abstracts, 1929, p. 280, and 1928, V. 5, p. 584).

HIGH GRID RESISTOR AMPLIFIER.—P. J. Mulder and J. Razek. (*Journ. Opt. Soc. Am.*, June, 1929, V. 18, pp. 466–472.)

A study of the increase of slope of the grid-bias/plate-current curve when very high resistances are included in the grid circuit. For a value of 2,710 megohms, the curve has an almost vertical portion, a change of 1/10 volt in bias producing a current change of 12 mA.; but at this extreme value of grid resistance the curve does not repeat if the change is made in the reverse direction. Grid resistances up to 1,800 megohms can, however, be used (with the particular valve employed—CX-312 A), with the advantage of a slope very much steeper than that given by the usual value of grid resistance. The difficulty lies in obtaining constant resistances of these high values; but the use of xylol made sufficiently conductive by the addition of small quantities of alcohol gave resistances which (when equilibrium conditions had been reached after the making) remained constant over periods of months.

USE OF THE THERMIONIC VALVE IN MEASUREMENTS OF IONISATION CURRENTS.—J. A. C. Teegan. (*Nature*, 20th July, 1929, V. 124, pp. 91–92.)

By the use of the voltage drop across a very high resistance (about 10^{11} ohms, from a 10 : 1 mixture of xylol and alcohol—*cf.* Mulder and Razek, above) the writer has used a single triode circuit to indicate ionisation currents, and now hopes to use it for the absolute measurement of such currents (of the order of 10^{-13}A.).

A VACUUM TUBE POTENTIOMETER FOR RAPID E.M.F. MEASUREMENTS.—H. M. Partridge. (*Journ. Am. Chem. Soc.*, No. 1, 1929, V. 51, pp. 1–7.)

A method which does not demand constancy of batteries, etc. The first valve has two grids, the

second one; the space-charge grid voltage of the former is simultaneously the anode voltage of the latter. The E.M.F. to be measured is applied to the control grid of the first valve: it is then replaced by a potentiometer E.M.F. (measured by a voltmeter) which is adjusted till the same current is produced in the second valve's anode circuit. The voltmeter then gives the required value of E.M.F.

Current Measurement with a Compton Quadrant Electrometer.—E. E. Watson. (*Proc. Camb. Phil. Soc.*, January, 1929, V. 25, Part I, pp. 67–74.)

With this instrument, using the "rate of deflection" method, currents of 10^{-14} ampere can be measured accurately in less than a minute.

A Direct-current Amplifier for Measuring Small Currents.—J. M. Eglin. (*Journ. Opt. Soc. Am.*, May, 1929, V. 18, pp. 393–402.)

Author's abstract:—A direct-current amplifier consisting essentially of a Wheatstone bridge, having the amplifying tube in one arm and a balancing tube in another, has been described by P. I. Wold and by C. E. Wynn-Williams [Abstracts, 1928, V. 5, p. 584]. This circuit has now been developed to give a constant amplification for currents in either direction up to 10,000 times the lowest measurable value. The amplification and the lowest measurable current are alterable together by changing the resistance introduced between the grid and filament of the amplifying tube. With tubes of high insulation, the amplification can be made as large as 10^6; and the measurable current as low as 10^{-14} ampere. Some improvements of the circuit are: (1) the insertion of a resistance in series with the tube in one arm of the bridge to "compensate" for variations in platé and grid battery voltages; (2) the suspension of the tubes to protect them from mechanical vibrations; (3) the use of tubes with pure tungsten filaments to avoid changes in contact potentials, and with plates enclosing the filaments completely to lower the effects of wall charges. In a "null" method of using the circuit the values of the grid resistance and an auxiliary potential introduced in the grid-filament circuit are sufficient to determine the measured current.

Die Verwendung von Blitzschutzlampen als Indikator-Röhren (The Use of Lightning-protector Lamps as Indicator-bulbs).—E. Hiedemann. (*Zeitschr. f. Unterr.*, No. 1, 1929, V. 42, pp. 27–28.)

The writer suggests that the common lightning-protector or over-voltage lamps have longer life and a lower lighting voltage than the special, rare-gas-filled resonance indicators used in wavemeters.

Frequency Measurements of Radio Waves Received, and Calibration of Wavemeters by Standard Frequencies Transmitted.—S. Ishikawa. (*Electrot. Lab. Tokyo*, Circular No. 59, April, 1929.)

In Japanese.

A Modulated Wavemeter: an Aid to Accurate Tuning and Distant Reception.—H. B. Dent. (*Wireless World*, 3rd July, 1929, V. 25, pp. 2–6.)

Description of the construction of a heterodyne wavemeter with modulating valve. *Cf.* "Constancy of Oscillator Frequency," August Abstracts, p. 457.

The Calibration and Construction of a Standard Frequency Meter.—T. D. Parkin. (*Marconi Rev.*, April, 1929, No. 7, pp. 18–28.)

Short Wave Signal Strength Measuring Apparatus.—T. L. Eckersley. (*Marconi Rev.*, May, 1929, No. 8, pp. 1–6.)

Beitrag zur Herstellung Konstanter Schwingungsfrequenzen eines Röhrengenerators (A Contribution towards the Production of a Constant Frequency in a Valve Generator).—F. Maske. (*Physik. Zeitschr.*, 1st April, 1929, V. 30, No. 7, pp. 197–201.)

By heterodyning a test circuit with a standard circuit, using a wavelength of 100 metres, the writer investigates the causes of frequency variation in valve oscillators, and particularly the influence of changes in filament current. He concludes that the effect of these changes is to alter the virtual capacity of the valve. This virtual capacity is in parallel with the oscillating circuit, and therefore its alteration changes the frequency of the latter: but it is connected to the oscillating circuit *through an anode condenser*, and from the properties of two condensers in series, therefore, it is possible to render the variations of the virtual capacity of the valve much less important, by making the anode condenser *small*. If, in any particular form of circuit, this condenser is shunted by a H.T. battery, the desired effect can still be obtained by the use of choking coils in the battery leads. The writer has thus obtained, for a 10 per cent. change of filament current, a frequency which was constant to 10^{-5} per cent.

Über die Konstanz elektrisch erregter mechanischer Schwingungen und ihre Anwendung (On the Constancy of Electrically Excited Mechanical Oscillations, and Their Application).—W. Hensel. (*Physik. Zeitschr.*, 1st May, 1929, V. 30, No. 9, pp. 274–278.)

Ein einfacher Versuch zur Bestimmung der Schwingungszahl einer Stimmgabel (A Simple Test for Determining the Frequency of a Tuning Fork).—K. Gentil. (*Zeitschr. f. Math. u. Nat. Unterr.*, No. 10, 1928, V. 59, p. 448.)

A gramophone record is placed upside-down on the turntable, scattered with lycopodium powder, and set to rotate 60 times per minute. The vibrating fork is then drawn slowly from the edge of the disc to the middle [presumably with an attached bristle touching the disc]. From the resulting spiral the frequency can conveniently be counted.

Neue Verfahren zur Koinzidenzvergleichung von Pendeluhren (New Methods of Coincidence-comparison for Pendulum Clocks).— —. Baltzer. (*E.T.Z.*, 27th June, 1929, V. 50, pp. 933–934.)

The use of the expensive and insufficiently accurate chronograph has recently been superseded by the coincidence method, in which a second clock is used which goes faster than the standard clock, and the number of swings between coincidences of the two pendulums is counted. The article describes the methods of avoiding mechanical contacts devised by Ferrié (photoelectric cell) and by Lejay (change of wavelength or intensity in short waves) and recent variations of these two methods.

Observations on Modes of Vibration and Temperature Coefficients of Quartz Crystal Plates.—F. R. Lack. (*Bell Tech. Journ.*, July, 1929, V. 8, pp. 515–535.)

The characteristics of quartz plates of the perpendicular or Curie cut are compared with parallel or 30-degree cut plates with reference to the type of vibration of the most active modes, the frequency of these modes as a function of the dimensions, and the magnitude and sign of the temperature coefficients of these frequencies. One of the various points emerging is that since both modes of the perpendicular cut crystals have a negative temperature coefficient, it is to be expected that it would be impossible to obtain zero temperature coefficient crystals with this orientation, as has been done with the parallel cut plates.

A High Precision Standard of Frequency.—W. A. Marrison. (*Bell Tech. Journ.*, July, 1929, V. 8, pp. 493–514.)

Author's synopsis :—A new standard of frequency is described in which three 100,000 cycle quartz crystal-controlled oscillators of very high constancy are employed. These are interchecked automatically and continuously with a precision of about one part in one hundred million. They are checked daily in terms of radio time signals by the usual method employing a clock controlled by current maintained at a submultiple of the crystal frequency. Specially shaped crystals are used which have been adjusted to have temperature coefficients less than 0.0001 per cent. per degree C.

Experiments on Magnetostrictive Oscillators at Radio Frequencies.—J. H. Vincent. (*Nature*, 6th July, 1929, V. 124, p. 41.)

A short note on a paper read before the Physical Society on 24th May. An account was given of the behaviour of two oscillators of different length in an oscillating circuit. The frequency of the smaller oscillator was 540 kc. per sec.

Piezoelectric Control Patents. (German, 472549, Lorenz, pub. 4th March, 1929; French, 651817, Soc. Mat. Tel., pub. 28th February, 1929.)

(1) To avoid over-straining the crystal, the latter is connected across a part only of the total capacity or inductance of the oscillating circuit. (2) The internal grid-anode capacity of the oscillator valve is neutralised (anode battery lead goes to mid-point of anode tuned-circuit inductance, and a neutrodyne condenser is connected between anode circuit and grid) in order to protect the crystal from overload.

Magnetostriktive Schwingungen (Magnetostrictive Oscillations).—E. Kopilowitsch. (*Ukr. Phys. Abh.*, No. 1, 1928, V. 2, pp. 19–22.)

A Thermostat Constant to One-thousandth of a Degree Centigrade.—F. R. Winton. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 214–217.)

Author's abstract :—A toluene-mercury thermoregulator, with variable-resistance contact in the grid circuit of a thermionic valve, controls the anode current which passes through a heating coil in the bath. One ten-thousandth of a degree Centigrade change of bath temperature is compensated by 5 to 10 per cent. change in heating current.

Magnetostriction : Remarks on Schulze's Results.—L. W. McKeehan. (*Zeitschr. f. Phys.*, No. 9/10, 1928, V. 52, pp. 752–754.)

Schulze's discovery that the magnetostrictive null point does not agree exactly with the minimum of hysteresis does not contradict the connection between the two properties.

Magnetostriction of Diamagnetic Substances in Strong Magnetic Fields.—P. Kapitza. (*Nature*, 13th July, 1929, V. 124, p. 53.)

Previous attempts to find magnetostriction in bismuth failed (*e.g.*, Van Aubel, 1903, using fields up to 3 kilogauss). The writer, using fields up to 300 kilogauss, obtained with an extruded bismuth rod a contraction only slightly larger than that expected from the "classical" magnetostriction (the stresses produced by the magnetic forces on the magnetic poles of the magnetised body) : but with a bismuth rod grown in a crystal, a larger effect was easily observed, which could be due only to the "atomic" magnetostriction. The writer's deductions from his results include the expectation that larger atomic magnetostriction would occur in substances where the atoms are not symmetrically bound, such as tin, tellurium and graphite.

Measurement of Atomic Distances by Piezo-electric Vibrations.—A. Meissner. (*Naturwiss.*, 11th January, 1929, V. 17.)

Lycopodium powder registration of H.F. vibrations of a circular disc of quartz, 15 mm. in diameter, was used to calculate the distances separating the silicon atoms in the quartz; the results agreed well with those obtained by the use of X-rays. The writer points out the remarkable accuracy (within a few per cent.) of the determination of structural dimensions of the order of 10^{-8} cm. from experiments made on an object of considerable size.

AN OPTICAL LEVER FOR MEASURING THICKNESS CHANGES OF MICA TO AN ACCURACY OF ABOUT 1.5×10^{-8} CM.—W. N. Bond. (*Phil. Mag.*, June, 1929, V. 7, No. 47, pp. 1163–1182.)

In a paper on "Certain Molecular Lengths Measured by an Optical Lever."

ON THE ULTRAMICROMETER OF DOWLING.—S. Ekelöf. (*Journ. Opt. Soc. Am.*, April, 1929, V. 18, pp. 337–341.)

A description of tests carried out during the past year with the Dowling circuit, using the capacity change method. With a tuned anode circuit and separate inductive reaction, it was found that the use of an appropriate grid battery increased the sensitivity considerably, to 0.1 mA. per 1 $\mu\mu$F. variation of capacity. The substitution of a grid-leak condenser combination, in place of the grid battery, increased the sensitivity to the high value of 4 mA./1 $\mu\mu$F. variation, and was particularly convenient as it was little influenced by stray capacities. If it were possible to keep working conditions (filament current, etc.) constant, such accuracy would enable measurements to be made of displacements as small as 10^{-9} mm.—*i.e.*, about 1/100 of the diameter of the hydrogen atom! The writer considers that by using large capacity batteries and by taking other precautions, displacements less than 10^{-6} mm. could be measured, using plates of 4 cm. radius spaced 0.1 mm. He describes the use made of a much less sensitive form of the apparatus, in investigating a hydroelectric engineering problem—the fracture of long steel lamels (forming ice-racks for turbines) from fatigue due to vibration.

AN INSTRUMENT FOR MEASURING SMALL AMPLITUDES OF VIBRATIONS.—W. Bragg. (*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 196–197.)

The use of a simple device by which the small amplitudes are measured by moving away a chattering contact and observing the point at which chattering stops.

BEOBACHTUNG UND REGISTRIERUNG VON DICKENÄNDERUNGEN DÜNNER DRÄHTE (Detection and Recording of Thickness Variations in Thin Wires).—W. W. Loebe and C. Samson. (*Zeitschr. f. tech. Phys.*, October, 1929, V. 9, pp. 414–419.)

An application of the ultra-micrometer principle to the investigation of thin wires (*e.g.*, tungsten filaments).

THE HIGH FREQUENCY ULTRA-MICROMETER.—L. Richtera. (*Elektrot. u. Masch : bau*, 27th January, 1929, V. 47, pp. 76–78.)

Various new applications are discussed, together with the substitution of recording methods for those depending on aural observation.

THE HETERODYNE NULL METHOD OF MEASURING DIELECTRIC CONSTANT.—P. N. Ghosh and P. C. Mahanti. (*Nature*, 6th July, 1929, V. 124, p. 13.)

From their own experiences, the writers suggest two possible sources of error in the process which may account for the discrepancies in the results of various workers. Taking precautions against these, they have obtained the value 1.000579 ± 4 for dry and carbon dioxide-free air at N.T.P.

MESSUNG DER DIELEKTRIZITÄTSKONSTANTEN UND DER SCHEINBAREN LEITFÄHIGKEIT VON ISOLIERSTOFFEN BEI HOCHFREQUENZ (The Measurement of the Dielectric Constant and Apparent Conductivity of Dielectrics for High Frequencies).—H. Kühlewein. (*Zeitschr. f. tech. Phys.*, July, 1929, V. 10, No. 7, pp. 280–288.)

By variation of the capacity of an oscillatory circuit loosely coupled to a transmitter, the resonance curve is taken. The capacity is composed of two condensers, the variable standard condenser and the test condenser (into which the dielectric under test can be introduced) connected in parallel. The dielectric is then introduced into the test condenser and the curve again taken. The two resonance curves show a displacement due to the change of capacity of the test condenser caused by the introduction of the dielectric. From this displacement the dielectric constant can be calculated. From the two curves the two logarithmic decrements can be obtained, and from their difference the apparent conductivity of the dielectric can be reckoned. Two different arrangements are used: for wavelengths greater than 600 m. the indicator is a double-thread electrometer in parallel with the condensers, for shorter wavelengths a hot-wire milliammeter is connected in series with the oscillatory circuit. Typical examples of tests by the method are given.

A TESTING SET FOR TRANSMITTING VALVES.—Y. Kusunose. (*Electrot. Lab. Tokyo*, Circular No. 57, April, 1929.)

In Japanese. The set is capable of testing valves with an input up to 40 kw. at an anode voltage up to 20 kv., on wavelengths from 100 to 5,000 m.

APPAREIL À LECTURE DIRECTE POUR LA MESURE DES CHAMPS MAGNÉTIQUES "GAUSSMÈTRE" (Direct-reading Instrument for the Measurement of Magnetic Fields: the Gaussmeter).—G. Dupouy. (*Bull. d. l. Soc. franç. d. Élec.*, April, 1929, V. 9, pp. 348–370.)

This instrument depends on the torque produced by the field on a magnetically anisotropic crystal (*e.g.*, $FeCO_3$, siderose, or Fe_2O_3, oligiste). This torque is opposed by a spiral spring or by the torsion of a wire. The scale is calibrated by a Cotton balance or other apparatus. Advantages are:—direct reading; the small size of the crystal allows an almost point by point exploration of the field. A disadvantage is a slight variation of the torque with temperature, but this can be compensated for.

SHIELDING AND GUARDING ELECTRICAL APPARATUS USED IN MEASUREMENTS—GENERAL PRINCIPLES.—H. L. Curtis. (*Journ. Am.I.E.E.*, June, 1929, V. 48, pp. 453–457.)

This abridgment of the first part of a symposium of six papers concludes with a bibliography of 18 items.

AN AREA-COMPUTING SCALE. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 230–231.)

A transparent scale engraved with a radial arrangement of graduated lines, by which the approximate areas of plane figures of regular or irregular shape can be determined. *See* R. W. K. Edwards (*Proc. Roy. Soc.*, V. 73, 1904) for the principles involved.

COMPENSATING ZERO SHUNT CIRCUIT.—J. Razek and P. J. Mulder. (*Journ. Opt. Soc. Am.*, June, 1929, V. 18, pp. 460–465.)

The stabilisation of the single triode zero shunt circuit voltmeter, by using the same potential divider to supply both anode and balancing voltages, was suggested by Wynn-Williams in 1927. The present paper investigates his circuit mathematically.

SUBSIDIARY APPARATUS AND MATERIALS.

A LOW POWER AUDIO-FREQUENCY CURRENT SUPPLY FOR GENERAL LABORATORY USE.—C. W. Oatley. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 217–220.)

This tuning-fork generator derives its power entirely from the 100-volt D.C. lighting mains, and provides 180 cycle A.C. of constant frequency and good wave-form. Current from the mains passes in succession through (*a*) a choke of a few henrys (which has proved sufficient to eliminate all mains hum), (*b*) two magnetising coils around, but not touching, the prongs of the fork near the bend, (*c*) a lamp resistance and a resistance for grid-bias supply, and (*d*) the filament of a 3-electrode valve. Between the prongs of the fork are two soft iron cylinders; one of these has a winding controlling, through a transformer, the grid of the valve; the second has two windings, one carrying the anode supply, the other leading to the output terminals.

In order that there shall be no mutual interference when several observers are using the generator simultaneously, it is essential that each take only a negligibly small amount of power from the source. Each observer therefore (or each laboratory bench) has a separate one-valve amplifier, the input voltage of which is supplied by the fork.

ALTERNATORS AND ROTARY TRANSFORMERS FOR A.C. OF HIGH FREQUENCY.—(French Patent 647166, Bunet, published 1st November, 1928.)

A diagram and short description of the special design of pole face, windings, etc., is given in *Génie Civil*, 15th June, 1929, p. 588.

A NEW ELECTRICAL RECORDING SYSTEM.—B. H. C. Matthews. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 220–226.)

Author's abstract :—" This paper describes a new form of moving iron oscillograph, and a valve amplifier designed to work with it, for the recording of very small and rapid fluctuations of E.M.F. Moving systems have been used having natural vibration frequencies of up to 10,000 per sec. The instrument gives fairly accurate records of potential waves of about 30 microvolts [in a circuit of 10,000—500,000 ohms] with a duration of about 2 milliseconds. The system, though rapid and sensitive, is electrically unbreakable. A new form of standing wave camera is also described." The oscillograph is on the telephone-receiver principle, the steady pull of a magnet on an armature being modulated by coils round the pole-pieces.

DAS THERMOELEMENT TE/BI UND SEINE PRAKTISCHEN ANWENDUNGEN (The Tellurium-Bismuth Thermoelement and its Practical Use).—M. A. Lewitsky and M. A. Lukomsky. (*Physik. Zeitschr.*, 1st April, 1929, V. 30, No. 7, pp. 203–205.)

Although this is the most sensitive of all known couples, it has not hitherto been made use of owing to the irregularity of the electrical properties of tellurium, and also to its brittleness. The writers appear to have overcome these difficulties to a great extent in their design, largely by the use of constantin wire as the lead which is fused into the tellurium. See also Lange and Heller, *ibid.*, 1st July, 1929, V. 30, No. 13, pp. 419–425.

VAKUUMTECHNISCHE NEUERUNGEN AN KATHODENOSZILLOGRAPHEN (New Methods of Vacuum Technique for Cathode Ray Oscillographs).—M. Knoll. (*Zeitschr. f. tech. Phys.*, July, 1929, V. 10, No. 7, 294–299.)

The use of rubber or lead washers in the place of the usual fat- or pizein-washers presents many advantages. Elastic metal packing for stuffing-boxes is now used to allow the adjustment of movable parts. High-vacuum taps in metal effect a considerable shortening of the time spent in exhausting. Finally, a vacuum-testing Geissler tube, readily replaceable, acts as an indicator permanently in position.

EIN- UND AUSFÜHRUNG VON PLATTEN UND FILMEN AN KATHODENOSZILLOGRAPHEN OHNE STÖRUNG DES HOCHVAKUUMS (Introduction and Removal of Plates and Films in Cathode-ray Oscillographs without Disturbing the High Vacuum).—P. Hochhäusler. (*E.T.Z.*, 13th June, 1929, V. 50, pp. 860–864.)

After discussing the various systems of external recording (photographing the fluorescent screen; passing the ray out through a Lenard window—of thin metal: no reference is made to the thin glass window referred to in June Abstracts, p. 341) and their disadvantages in reducing the speed of recording and the intensity of the ray respectively, the writer describes the method devised by himself and Schwenkenhagen for combining the advantages of external and internal recording, for continuous records. The film is stored inside the vacuum and is led out through a mercury-filled rectangular-sectioned tube on the barometer principle. It was found that this procedure does not affect the vacuum, nor is the sensitive layer injured by passage through the mercury. The film has to be guided by smooth guiding-rods so that the surface tension of the mercury does not force it against the sides of the tube. An oscillograph made on this principle is described and illustrated. The pointer-length of the ray is only 40 cm., but the sensitivity is kept up to 10 v. per mm. deflection by bringing the

deflecting plates very close to the ray by adjustment during a run: this adjustment is by rotating the plates which are mounted on a slant on their spindles. The paper then describes an arrangement for using photographic plates inside the vacuum and releasing them into the open air by means of a trap, without the complications of the "ante-vacuum" used by Rogowski (Abstracts, 1928, V. 5, p. 690). Various other new arrangements are described, such as that for giving the time base, and for leading-in the deflecting plates and anode (plugs comprising copper fused into glass are here used).

ON SOME VACUUM RECORDING GAUGES.—K. C. D. Hickman. (*Journ. Opt. Soc. Am.*, April, 1929, V. 18, pp. 305–331). *And* A MODIFIED PIRANI VACUUM GAUGE.—T. De Vries. (*Ibid.*, pp. 333–335.)

RECTIFICATION OF ALTERNATING CURRENT, ESPECIALLY AT HIGH TENSION.—(French Patent 653538, Philips' Co., published 22nd March, 1929.)

In discharge-tube rectifiers for high-tension currents, a reverse flow is prevented by separating sufficiently the cathode and anode. This may lead to a difficulty in procuring a current flow in the desired direction. According to the present invention, the main, high-tension tube has one or more auxiliary electrodes between cathode and anode connected to the anode through a small auxiliary rectifier, with suitable resistances in series to limit the current through that rectifier. The connections are such that the auxiliary electrodes of the main tube only facilitate the passage of current when a current is passing in the right direction in the auxiliary tube.

LES REDRESSEURS AU TANTALE (Tantalum Rectifiers).—J. Innocenti. (*T.S.F. Moderne*, August, September, November, December, 1928, and January, 1929.)

A NEW RANGE OF DRY METAL RECTIFIERS: A VOLTAGE-DOUBLING BRIDGE CIRCUIT WITH FULL-WAVE RECTIFICATION ON TWO RECTIFIER UNITS.—(*Wireless World*, 17th July, 1929, V. 25, p. 57.)

SUPPRESSION OF SECONDARY FREQUENCIES IN STATIC FREQUENCY MULTIPLIERS: COMMENTS AND REPLY.—H. Freese. (*Zeitschr. f. Hochf. Tech.*, June, 1929, V. 33, pp. 223–225.)

Comments by Kramar and Gutzmann on the paper dealt with in May Abstracts, pp. 280–281, with replies by the author.

LES REDRESSEURS À OXYDE DE CUIVRE (Copper Oxide Rectifiers).—M. Demontvignier. (*L'Onde Élec.*, May, 1929, V. 8, pp. 192–209.)

The theory of action, calculations of voltage drop and efficiency, construction, and applications to Wireless are here discussed by an engineer of the company manufacturing the Rectox (Hewittic) rectifier.

THE ALUMINIUM ELECTROLYTIC RECTIFIER.—W. E. Holland. (*Trans. Am. Electrochem. Soc.*, V. 53, 1928, pp. 195–201.)

Recent improvements and points in operating are described.

TELEFUNKEN GLOW-DISCHARGE RECTIFIER FOR A.C. MAINS.—(*Rad., B., F., für Alle*, July, 1929, pp. 320–321.)

The Telefunken Company is now making the RGN 1500, a filament-less rare-gas rectifier of the type hitherto chiefly used in the U.S.A.

DIE PHYSIKALISCHE NATUR DER ELEKTRISCHEN VORGÄNGE IN HOMOGENEN ISOLATOREN (The Physical Nature of the Electrical Processes in Homogeneous Insulators).—A. Smurow. (*Arch. f. Elektrot.*, 8th May, 1929, V. 22, No. 1, pp. 31–61.)

A lecture under the same title, with a long subsequent Discussion, is fully reported in *E.T.Z.*, 23rd May, 1929, V. 50, pp. 768–773.

THE PROPERTIES OF DIELECTRICS. I.—ELECTRIC MOMENT AND MOLECULAR STRUCTURE.—C. P. Smyth. (*Journ. Franklin Inst.*, June, 1929, V. 207, pp. 813–824.)

THE DETERMINATION OF THE DIELECTRIC CONSTANTS OF IMPERFECT INSULATORS.—R. L. Lattey and O. Gatty. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 985–1004.)

CARBOLITE, ITS PRODUCTION AND PROPERTIES.—P. A. Florensky. (*U.S.S.R. Scientific Tech. Dept.*, No. 238, 1928.)

In Russian with French summary. Carbolite is a dielectric discovered by the Russians: one form of it is made by the condensation of tricresol with formol. It possesses a number of advantages over other similar materials, being very tractable—it can be moulded, turned, etc., etc.

BREAKDOWN OF SOLID INSULATORS; OF GLASS IN D.C. AND ALTERNATING FIELDS; OF PORCELAIN; OF IMPREGNATED PAPER. ON THE HEAT THEORY OF ELECTRICAL BREAKDOWN; ETC.—Walther, Kobeko and others. (*Trans. Phys. Tech. Lab. Leningrad*, No. 5, 1928.)

In Russian.

DIELEKTRIZITÄTSKONSTANTE UND LEITFÄHIGKEIT TECHNISCHER ISOLIERSTOFFE UND DIE GESTALTUNG DER STROMKURVE BEIM STROMDURCHGANG (The Dielectric Constant and Conductivity of Commercial Insulating Materials, and the Form of the Current Curve).—P. Böning. (*Zeitschr. f. tech. Phys.*, July, 1929, V. 10, No. 7, pp. 288–294.)

Author's summary:—It has been shown (Abstracts, 1928, p. 523, and 1929, p. 405) that the dielectric constant and also the conductivity of commercial dielectrics are apparently dependent on the voltage. The relations are here developed further, particular attention being given to their range of validity. A theoretical and experimental

investigation is then made of the shape of the current curve when a circuit containing a condenser with such dielectric is submitted to a sinusoidal voltage.

DESIGN METHODS FOR SOFT MAGNETIC MATERIALS IN RADIO.—J. Minton and I. G. Maloff. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1021–1033.)

"Radio transformer design is usually complicated by the effect of passing d-c space current through the winding or by the use of an air-gap to prevent saturation of the core by unidirectional current. The procedure to follow when one of these disturbing effects is present is not very difficult, but it becomes somewhat involved if an efficient design is wanted when both are present. In this paper an attempt is made to present a workable method of taking account of these disturbing effects. The method involves the determination of the apparent and maximum obtainable permeabilities of the magnetic materials, so that a proper conclusion may be arrived at by an application of simple engineering methods."

SHADED MAGNETIC FIELD OF A.C. MAGNETS.—N. Andersen. (*Elect. Journ.*, February, 1929, V. 26, pp. 82–85.)

A device for obtaining quiet operation of an A.C. magnet on a closed gap, by which a pull is obtained during the complete cycle.

LES ALLIAGES LÉGERS DE HAUTE CONDUCTIVITÉ: LEUR EMPLOI DANS LA CONSTRUCTION DES LIGNES ÉLECTRIQUES (Light Alloys of High Conductivity: their Use in the Construction of Electric Lines).—H. Chaumat. (*Rev. Gén. de l'Élec.*, 4th May, 1929, V. 25, pp. 687–689.)

CONSTANT SPEED COUPLING.—J. P. Hall & Co. (*Engineering*, V. 126, p. 771.)

A non-electrical, centrifugal-force opposing-spring coupling is described which, when the motor speed was varied from 455 to 760 r.p.m., allowed the speed of the (8 kw.) dynamo to change only from 430 to 455 r.p.m.

AUTOMATIC CONTROL OF FREQUENCY AND LOAD.—H. A. McCrea. (*Gen. Elec. Review*, June, 1929, V. 32, pp. 309–313.)

A description of the Warren Frequency Control Equipment for power stations. Where manual operation results in instantaneous frequency variations of one-tenth of a cycle, this equipment limits them to one-fortieth of a cycle.

"STABILIZZAZIONE" DI ACCENSIONE PER APPARECCHI COMPORTANTI TUBI E VALVOLE TERMOIONICHE (Stabilisation of Filament Current for Thermionic Tube and Valve Apparatus).—E. Pugno-Vanoni. (*Elettrotec.*, 15th May, 1929, V. 16, pp. 339–340.)

A method, for alternating current, depending on a "constant intensity transformer" with an auxiliary primary winding connected in series with the leads to the apparatus carrying the main load, and a secondary which "arranges itself in a suitable position under the opposing influences of gravity and electrodynamic repulsion." This secondary is connected to the primary of an insulating transformer, whose secondary goes to the filament. Excellent test results are given.

A NEW AUTOMATIC A.C. VOLTAGE REGULATOR.—K. Howe. (*Rad. Engineering*, March, 1929, V. 9, p. 40.)

The numerous applications for this device, and some indications of its performance, are given here; as regards its actual nature, it is stated that "like the conventional transformer, the regulator consists of primary and secondary windings and a special core shape employed to produce regulation. Unlike transformers, the placement of windings in respect to the others and the cross-section of the core have very marked effects. . . ." *Cf.* above, Pugno-Vanoni.

EINE AUSGLEICHSSCHALTUNG MITTELS NORMALER METALLFADENLAMPEN (A Stabilising Arrangement using ordinary Metal-filament Lamps).—H. Roder. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 80–82.)

By making use, through a bridge connection, of the difference between the current-voltage curves of an ordinary resistance and of a metal-filament lamp, a voltage stabiliser is obtained which can be used for A.C. or D.C. For a 33 per cent. change in supply voltage (300 v. $\pm$ 33 per cent.) the greatest change in the working voltage (33 v.) was $\pm$ 1.4 per cent. An application suggested is in providing grid-bias in transmitters. The method is in theory applicable also to the stabilisation of power, but in this case its efficiency is very low (smaller than 2 per cent.).

STATIONS, DESIGN AND OPERATION.

KURZWELLENVERSUCHE BEI DER AMERIKAFAHRT DES LUFTSCHIFFES "GRAF ZEPPELIN" (Short-wave Tests on the American Flight of the Airship "Graf Zeppelin.")—(*E.T.Z.*, 3rd January, 1929, V. 50, pp. 16–18.)

Report of the Wireless Division of the DVL. Among the results mentioned the following may be noted:—On the outward journey the airship signals, from a set giving 2 watts to the (dipole) aerial, were received in Berlin practically without a break up to 4,000 kms., using wavelengths of 27–37 m. Short transmissions at irregular intervals (owing to airship trouble) gave good reception on about 20 m. up to 5,000 km. and weaker reception up to 5,500 km. Temporary breakdown of communication occurred during the twilight hours, for which period no special wave had been provided. It is concluded that work still needs to be done (*a*) in finding the suitable waves for various distances, and (*b*) in developing more powerful transmitters, up to the limits suitable for the various aircraft; "this limit, for an airship of the size of the LZ.127, should be about 100–200 w." [to aerial ?] While the breakdown of communication is attributed to the use of the wrong wavelength for the twilight hours, the frequent insufficient strength of signal was due to the power

being too small. The short-wave receiver on board the airship (push-pull "audion" with 3 L.F. stages) was much less affected by atmospherics than the long-wave receiver; but it was troubled by local disturbances which however can be guarded against.

DUPLEX ARRANGEMENTS.—(German Patents 471143, Telefunken; 464724 and 475535, Lorenz.)

(1) The same valve is used for transmission and reception, the reaction coupling only allowing oscillation to take place when the microphone is in action. (2) deals with the use of a directive, rotatable aerial for transmission and another independent one for reception: the direction of duplex communication can thus be altered by swinging the two aerials. (3) A bridge arrangement with one aerial only; the transmitted and received waves are so nearly equal in wavelength that their interference wave can be used in the receiver. Talking and calling switching arrangements are described.

DRAHTLOSES GEGENSPRECHEN (Duplex Wireless). —W. Hahn. (*E.T.Z.*, 11th July, 1929, V. 50, pp. 1019–1024.)

Author's summary:—"After mentioning the earlier experiments carried out by the German Post Office in conjunction with private firms, the fundamental circuits and the necessary steps for joining up to the telephone systems are discussed, special attention being given to the doubly- and singly-actuated reaction-stopper circuits. A description is given of the stability measurements carried out over the test service Berlin-Hamburg, on short waves, and of the fading effects within the speech-frequency band [selective fading] found during those tests. The equipments for the Germany-Argentine service, and its tests, are [briefly] described. [See also *E.T.Z.*, 20th June, 1929, p. 907.] The conclusion of the paper glances at future developments in duplex radiotelephony."

LA NOUVELLE CONVENTION RADIOÉLECTRIQUE DE PRAGUE ET LA SUPPRESSION DES INTERFÉRENCES ENTRE LES ÉMISSIONS DE RADIODIFFUSION (The New Prague Radio-electric Convention, and the Suppression of Interference between Broadcasting Stations).—M. Adam. (*Rev. Gén. de l'Élec.*, 13th July, 1929, V. 26, pp. 61–72.)

TELEPHONY WITH AUSTRALIA.—(*Electrician*, 19th July, 1929, V. 103, p. 69.)

An editorial paragraph on the re-broadcasting of the Westminster Abbey Thanksgiving Service throughout Canada by the Marconi-Mathieu multiplex (beam) system; the re-broadcasting was so good that the service was passed on to Australia over the Canada-Australia beam and was successfully re-broadcast in Australia. On the same day two-way telephony was conducted between England and Australia, using the same route. The paragraph remarks: "One would have thought that such an event, unique in the history of telephonic and telegraphic communication, would have been the subject of considerable publicity in the newspapers of this country, but so modest are we in these matters that even the lesser achievement of relaying the Thanksgiving Service to Canada resulted in many letters of congratulation being sent to the National Broadcasting Company—of America!"

ERÖFFNUNG DER UNMITTELBAREN FUNKBINDUNG DEUTSCHLAND-SIAM (Opening of the Direct Wireless Service between Germany and Siam).—(*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 90–91.)

DER WELTFERNSPRECHVERKEHR (The World's Telephone Service).—P. Craemer. (*E.T.Z.*, 4th July, 1929, V. 50, pp. 959–963.)

This general survey includes a world-map showing existing and projected services.

THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING.—G. A. Mathieu. (*Marconi Rev.*, April, 1929, No. 7, pp. 1–7.)

GENERAL PHYSICAL ARTICLES.

ÜBER DIE SYNTHESE VON ELEMENTEN (The Synthesis of Elements).—G. I. Pokrowski. (*Zeitschr. f. Phys.*, 21st March, 1929, V. 54, No. 1/2, pp. 123–132.)

The writer investigates the energy and frequency of the radiation which must be set free if single protons unite to form atomic nuclei of certain elements. He shows that the periods of these radiations must be whole multiples of "chronons." From considerations of energy he determines the most probable syntheses; the frequencies of the corresponding radiations agree completely with the observations of Millikan and Cameron on the cosmic rays. Finally he calculates the mass of the proton as 1667×10^{-24}, as compared with the experimental value 1662×10^{-24}. A second part appears in No. 9/10, 11th May, 1929, pp. 724–730. Here the writer shows that the loss of mass, on the union of proton and electron, fits in approximately with Aston's experimental law of atomic weight. He then calculates the thickness of the layer which emits the cosmic rays, and arrives at a figure of the same order of magnitude as the dimensions of the Galactic stellar system.

DIE NATUR DER HÖHENSTRAHLUNG (The Nature of the "Cosmic Rays.")—W. Bothe and W. Kolhörster. (*Naturwiss.*, 26th April, 1929, V. 17, pp. 271–273.)

A description of the tests, with two Geiger-Müller tube counters, referred to in June Abstracts, p. 344, leading to the conclusion that the "cosmic rays" are not a form of gamma radiation but are corpuscular rays.

PENETRATING RADIATION AND DE BROGLIE WAVES. —F. T. Holmes. (*Nature*, 22nd June, 1929, V. 123, p. 943.)

Referring to the Bothe and Kolhörster experiment from which these workers deduce a corpuscular rather than a wave nature for the "cosmic rays" (see June Abstracts, p. 344) the writer

suggests, from consideration of the de Broglie wavelength formula and the experiments of Davisson and Germer and of Kikuchi, that the Bothe-Kolhörster experiment may be inconclusive.

Über eine neue Art sehr schneller Beta-Strahlen (A New Kind of Beta-Radiation). —D. Skobelzyn. (*Zeitschr. f. Phys.*, 11th May, 1929, V. 54, No. 9/10, pp. 686–702.)

The hypothesis that the fast beta-rays of uncontrolled origin, which occasionally appear in a Wilson expansion apparatus, represent secondary electrons produced outside the chamber and in its walls by the ultra-gamma cosmic radiation, is here investigated experimentally. Results leave little doubt that the hypothesis is correct.

Sur la Nature des Rayons ultrapénétrants—Rayons cosmiques (On the Nature of the Highly Penetrating Radiations—Cosmic Rays).—P. Auger and D. Skobelzyn. (*Comptes Rendus*, 1st July, 1929, V. 189, pp. 55–57.)

Referring to Bothe and Kolhörster's verdict that these rays are corpuscular and not of the gamma type (June Abstracts, p. 344), the writers point out that their own recent discovery (of very rapid beta rays apparently produced as secondary radiations by ultra-gamma rays) would lead to a different explanation of the above-named workers' results with their two Geiger ion-counters. They suggest that the cosmic rays are non-ionising ultra-gamma radiations producing by the Compton effect very rapid beta-rays which cause the ionisation associated with the cosmic radiations.

Thunderstorms and the Penetrating Rays.—B. F. J. Schonland. (*Nature*, 20th July, 1929, V. 124, p. 115.)

"Measurements of the intensity of the penetrating radiation underneath five active thunderstorms [in S. Africa] did not differ appreciably from measurements made during periods of fine weather."

Bemerkung zur Natur der Höhenstrahlung (A Note on the Nature of the Cosmic Rays). —A. K. Das. (*Naturwiss.*, 5th July, 1929, V. 17, pp. 543–544.)

By a combination of relativity principles and quantum mechanics, the writer applies the results of Ornstein and Burger (that the radius of a photon is equal to the wavelength of its associated wave) and of McLewis (that the radius of a photon is equal to that of an electron) to show that the effects of the highly-penetrating radiations would be produced by hydrogen nuclei travelling with a velocity $0.7 \times$ velocity of light. He quotes the Bothe-Kolhörster pronouncement as to the corpuscular nature of the rays as fitting in with his theory. A study of the behaviour of the rays in an electric and magnetic field would test its correctness.

Cosmic Radiations and Evolution.—J. Joly. H. H. Dixon. (*Nature*, 29th June, 1929, V. 123, p. 981.)

The first letter points out that there seem to be no sure grounds for believing that the penetrating radiations are uniformly distributed through space. If they are not, and if considerable variations in the strength of those reaching the earth have occurred in the past—possibly referable to translatory movements of the solar system—serious effects upon organic evolution may have taken place. Thus if the present small value of their energy is the result of a recent decrease, the conclusions of medical research on the effect of gamma and X-ray radiation on healthy and morbid tissue might suggest "an issue of rather sensational kind, and certainly at present purely speculative": —that the present world-wide increase of cancer may be due to the disappearance in recent times of a controlling factor which acted in the same manner as gamma or X-rays upon animal tissues.

The second letter refers to the above suggestion and to the recent discovery of the production of variation in the progeny of plants by the treatment of the parents with X-rays; the writer suggests that the cosmic radiations have been a factor in the production of variations by direct action on the germplasm.

MISCELLANEOUS.

Luminous Discharge in Gases at Low Pressures. —H. Pettersson. (*Nature*, 29th June, 1929, V. 123, pp. 978–979.)

Further development of the work on the electrodeless discharge referred to in July Abstracts, p. 404. The use of short coils in place of the Lecher circuit previously employed greatly increases the luminosity, and allows the discharge to be passed through quartz capillaries less than a millimetre in width. A source of light is thus obtained which is suitable in shape for spectrography and requires a very minute quantity of the gas to be examined. With a plate current of, say, 50 mA. at an anode potential of 1,000 v., the luminosity in the case of the inert gases is very intense, neon giving light of an intensity almost insupportable to the eye both in narrow capillaries and in wider tubes. Possibly experiments will show that krypton thus excited will be a suitable source of the line at 5,649 A.U., recently proposed as a new standard of wavelength. Various dissociation and spectroscopic effects are described.

Vital Rays.—(*Nature*, 13th July, 1929, V. 124, pp. 50–51.)

A review of Reiter and Gábor's book, "Zellteilung und Strahlung" (Cell Division and Radiation). The reviewer outlines the history of the theory (originated by Gurwitsch) of mitogenetic rays emitted by growing roots, bulbs, yeast cells and other living tissues or substances. Gurwitsch assumes that just as light-production in organisms is supposed to be due to a reaction between luciferin and luciferase, so these rays arise when "mitotin," which is killed by heat, unites with "mitotase" which survives a temperature of 60 deg. It has been claimed that in full-grown animals only the blood produces the rays, and more recently that the tissues of malignant tumours emit them. Their wavelength is supposed to be about 190–230 $\mu\mu$. The work under review gives experimental results in detail, confirms Gurwitsch's main statement and

supports many of the hypotheses and conclusions arrived at by him and his co-workers.

SUR L'UTILISATION DE L'ÉNERGIE THERMIQUE DES MERS (The Utilisation of the Thermal Energy of the Seas).—G. Claude. (*Comptes Rendus*, 3rd June, 1929, V. 188, pp. 1460–1461.)

The writer has just discovered, in a *Revue Scientifique* of 1881, a communication from D'Arsonval anticipating the plan of Claude and Boucherot (Abstracts, 1928, V. 5, pp. 471–472), though suggesting the use of liquefied gas instead of the vapour of the water itself.

UTILISATION DES SOURCES D'ÉNERGIE NATURELLE (Utilisation of Sources of Natural Energy).—P. Drosne. (*Chaleur et Industrie*, February, 1929, V. 10, pp. 75–77.)

A somewhat pessimistic article on such plans as those of Claude and Boucherot (*see* above). The writer considers that such schemes suffer from restrictions analogous to those which limit the utilisation of the tides.

ON THE WRITING OF SCIENTIFIC PAPERS.—W. H. Merriman. (*E.W. & W.E.*, July, 1929, V. 6, p. 384.)

Referring to Colebrook's article (August Abstracts, p. 466) the writer suggests an omitted point of importance—the choice of a title which shall be concise, readily keyed for a subject-matter index, and not a "verbal procession" as is so often the case.

RECENT DEVELOPMENTS IN EDUCATIONAL BROADCASTING.—H. L. Fletcher. (*Journ. R. Soc. Arts*, 19th July, 1929, V. 77, pp. 872–895.)

APPLICATION DE LA THÉORIE ÉLECTRONIQUE AUX MAUVAIS CONTACTS (Application of the Electronic Theory to Imperfect Contacts).—H. Pélabon. (*L'Onde Élec.*, April, 1929, V. 8, pp. 160–170.)

Author's summary :—"The writer first recalls how the electrons are distributed in the interior and at the surface of a conductor. He lays stress on the difference of velocity of passage of these electrons in a perfect and in an imperfect contact. He then deduces from this expressions for the intensity of the direct and alternating currents in a circuit containing an imperfect contact. He also explains the rectifying action of contacts formed by identical metals in which one electrode is mobile. He considers the influence of electromagnetic shocks and shows that coherer effects are due to the displacement of the electrodes. He suggests an explanation of the negative coherer-effect found by Branly for lead dioxide." *Cf.* July Abstracts, p. 402 ; also April, p. 226, and Audubert and Quintin, same page.

SUR L'EXISTENCE D'UN ÉTAT CONDUCTEUR DES LIQUIDS DITS ISOLANTS (On the Existence of a Conducting State in So-called Insulating Liquids). — L. Brüninghaus. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1386–1388.)

Experimental investigations have led to the following conclusions :—that below thicknesses of the order of one hundredth of a millimetre, and under the application of p.d.'s of the order of some 10–110 volts, insulating liquids can suddenly acquire metallic conductivity ; that this modification is reversible ; that it makes its first appearance in the form of an unstable state where the two régimes, conducting and insulating, are intermingled erratically. The writer has assured himself that there is no sparking or short circuiting. He points out that the phenomenon fits in with the known improvement of moving contacts by a film of vaseline, etc.

BEITRAG ZUR KENNTNIS DER VORGÄNGE BEIM STROMDURCHGANG DURCH DEN MENSCHLICHEN KÖRPER (Contribution to our Knowledge of the Processes involved in the Passage of Current through the Human Body).—(*Bull. d. l'Assoc. Suisse des Élec.*, 7th July, 1929, V. 20, No. 13, pp. 428–441.)

These tests lead to the conclusion that under adverse conditions, and when circuit is made from hand to hand, 30 v. can be fatal for dry and 20 v. for wet hands. For a person in a bath, taking hold of a charged tap or lamp, the limit is reduced to 10 v. *Cf.* February Abstracts, p. 115.

RADIO IN TRAINS.—(*Journ. Am.I.E.E.*, June, 1929, p. 446.)

A paragraph on recent successful tests in Canada, where the signals from the train were transferred to the neighbouring telegraph wires and thence (at the terminal point) to the telephone system. At present, the terminal points must not be more than 150 miles apart or the voice is lost.

FOG LANDING FOR AEROPLANES.—(*See* Dellinger & Diamond, under "Directional Wireless".)

Some Recent Patents.

The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

HIGH-EMISSION FILAMENTS.

Application date, 1st December, 1927. No. 307099.

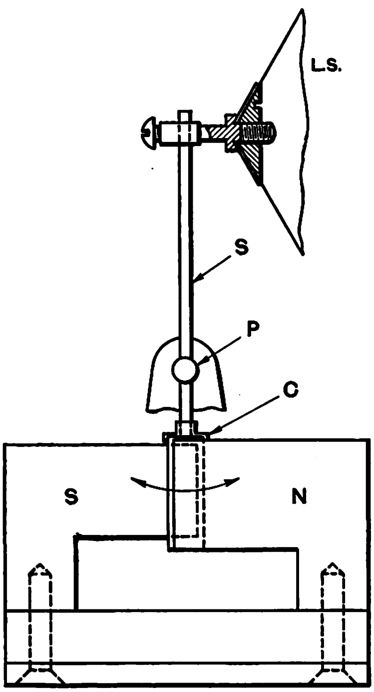
A nickel or platinum core is immersed in alkaline-earth metal powder and heated *in vacuo* for a considerable time, whereby the metal vapour so produced penetrates the core. No definite oxidising treatment is necessary. It is stated that the alkaline-earth metal diffuses through the core to form a molecular layer at its surface. In operation the oxygen or other gas necessary for high emission is furnished by the small quantity occluded in the electrodes of the finished valve.

Patent issued to E. Y. Robinson and Metropolitan-Vickers Electrical Co., Ltd.

MOVING-COIL SPEAKERS.

Application date, 30th November, 1927. No. 310759.

The moving coil *C* is located in the narrow gap formed between two pole pieces *N, S*, the former being of horseshoe shape with the point of the latter entering between its two horns. The coil is therefore vibrated in the direction of the arrows and communicates its movement to a spindle *S*, which is pivoted at a point *P* between the moving coil and the cone *L S* of the speaker. The point *P* is so chosen that the amplitude of movement of the diaphragm or cone is twice that of the coil *C*.



No. 310759.

Patent issued to The British Thomson Houston Co., Ltd., and A. P. Young.

INDIRECTLY HEATED VALVES.

Application date, 5th December, 1927. No. 307327.

The heating element is disposed inside a tubular emitter or cathode consisting of a number of different layers. The outer layer is a coating of alkaline-earth oxide having a high emissivity, laid on a layer of soft iron which serves as a magnetic screen for any field arising from the heating element. A second inner layer consists of a metal such as nickel and a refractory metallic oxide, the mixture having a high thermal and a low electrical conductivity. The last or inner layer consists of a metal such as platinum of high electrical conductivity. The heater element may be connected at its mid-point to the centre of the composite cathode.

No. 307326. The true cathode is heated by a positive ion bombardment from an auxiliary electrode to which the mains voltage is applied. The system is particularly suitable for gas-filled rectifiers, but may also be applied to "hard" valves by coating the surface of the heating-electrode with a mixture of magnetite, aluminium oxide, and cæsium nitrate, which gives a copious positive ion emission.

No. 307325. Here the emitter is energised by heat derived from dielectric losses set up across a condenser to which the mains voltage is directly applied. The dielectric material is zirconia, thoria, silica, or other refractory substance. The latter may be regarded either as an imperfect dielectric or as a very poor conductor. The heat resulting from the application of the A.C. mains voltage is radiated to the emitter or cathode of high emissivity.

Patent issued to Graham Amplion, Ltd., and P. Freedman.

DIRECTIVE AERIALS.

Convention date (Holland), 3rd October, 1927. No. 298131.

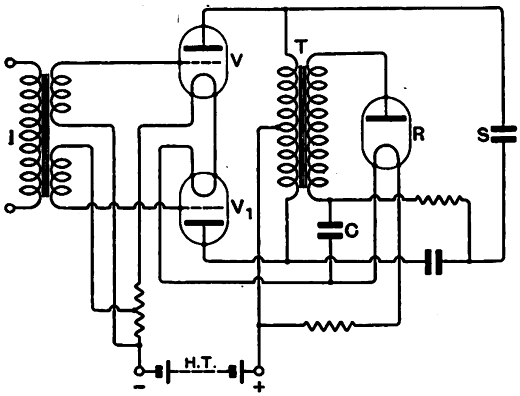
A directive aerial system consists of a symmetrical two-wire feed-line, to which are directly connected a series of radiating "doublets" arranged to extend on each side of the feeders. The radiators may be spaced half a wavelength apart, in which case the connections to the feeder are alternately crossed so as to maintain the currents in phase. Or they may be spaced a full wavelength apart and fed without crossing. It is stated that the phase relation is not affected by reflection at the tapping points, and that each doublet receives an equal quantity of current from the common feeder.

Patent issued to N. Koomans.

ELECTROSTATIC LOUD SPEAKER CIRCUITS.

Convention date (Germany), 10th November, 1927. No. 300252.

In order to increase the available voltage used for biasing a loud speaker of the electrostatic type, the speech frequency currents from a pair of L.F.



No. 300252.

amplifiers is rectified and used for this purpose. Acoustic currents from an input transformer *I* are applied to a pair of push-pull amplifiers *V*, V_1. The output is applied across the plates of an electrostatic loud speaker *S*, in addition to a D.C. biasing voltage from a battery *H.T.*, or from D.C. mains. As the speaker is voltage-operated, a transformer *T* is shunted across the valves *V*, V_1, the secondary voltage being applied to a rectifier *R* and charges up a condenser *C*. The effective biasing voltage across the loud speakers is thus made equal to that supplied by the source *H.T.* and that built up across the condenser *C*.

Patent issued to E. Reisz.

ELECTROSTATIC PICK-UPS.

Application date, 26th September, 1927. No. 306855.

To connect an electrostatic gramophone pick-up to a wireless receiver, the detector valve is first removed, and an adaptor plugged into its place. The valve is then replaced in sockets on the upper face of the adaptor. The internal connections of the adaptor include a high-resistance and leak inserted between the grid and filament. An extra lead is connected to the positive of the high-tension supply to provide the necessary biasing voltage for the pick-up. A special screening lead is twisted around the feed connections.

Patent issued to H. Andrewes and Dubilier Condenser Co. (1925), Ltd.

PIEZO CRYSTAL MOUNTINGS.

Application date, 20th February, 1928. No. 309276.

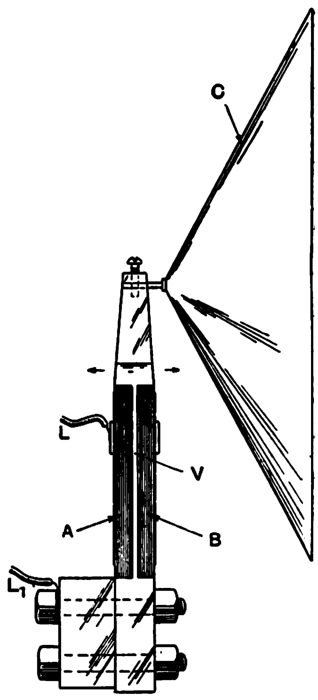
When a piezo crystal is subjected to the influence of modulated high-frequency oscillations, it tends to react as an electrical circuit of very low damping to the fundamental or carrier frequency. Accordingly it may fail to respond in the desired manner to the sideband components of modulation. To prevent this the crystal mounting is so arranged as to offer a definite mechanical or frictional damping to oscillations within the critical range. For instance, it may be mounted on a rubber block; or an air gap may be left of such size as to set up standing air-waves which produce the desired degree of friction.

Patent issued to The Gramophone Co., Ltd.; A. Whitaker, W. F. Tedham, and C. O. Browne.

A PIEZO-ELECTRIC SPEAKER.

Convention date (U.S.A.), 14th October, 1927. No. 298904.

The diaphragm of a loud speaker is driven by the reaction of a piezo-electric unit to the amplified speech-currents. The cone *C* is supported by a light metal member which is cut away to form a thin central vane *V* on each side of which is mounted a long section of piezo-electric material *A*, *B*. The crystal sections are so cut that one expands longitudinally whilst the other simultaneously contracts under the action of an applied voltage, thus tending to vibrate the member *V* in the direction of the arrows. Speech voltages are applied through conductors *L*, L_1, the former contacting with a metal foil covering the outer surface of both crystals and the matter with the central vane *V*.



No. 298904.

Patent issued to E. W. C. Russell.

DIRECTION-FINDING.

Convention date (Holland), 6th December, 1927. No. 301831.

In order to prevent losses due to the use of sliding contacts between a rotating frame aerial and the input circuit of the receiver, the primary coil of the aerial transformer is wound rigidly around the supporting spindle of the aerial, whilst the secondary coil is wound around a stationary sleeve enclosing the spindle. The coupling remains constant for normal rotation, but can be adjusted to any desired value by moving the sleeve axially along the spindle.

Patent issued to Nederlandsche Telegraf Co.

PIEZO-CONTROLLED OSCILLATORS.

Convention date (U.S.A.), 21st March, 1927. No. 287484.

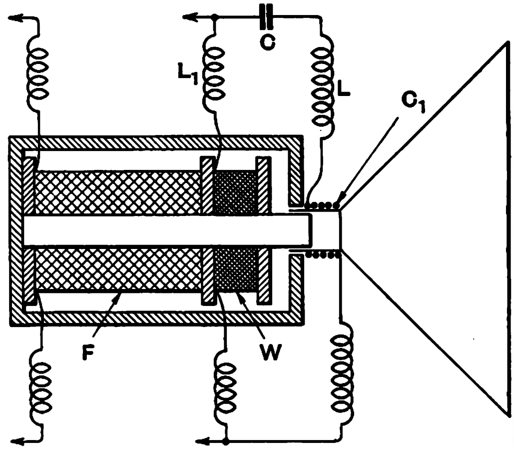
It is stated that the degree of control exercised by a crystal upon an oscillation circuit is an inverse function of the amount of regeneration necessary to make the crystal oscillate. Accordingly a more forceful arrangement than those hitherto known is obtained by combining the control crystal with means for stabilising or neutralising the inherent internal capacity of the valve oscillator, so as to reduce regenerative action to a minimum.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

LOUD-SPEAKER FILTER CIRCUITS.

Application date, 12th November, 1927. No. 311430.

The direct-current component passing through the choke coil of an output filter circuit is used to augment the normal exciting-current for the field-magnet of a moving-coil speaker. As shown in the Figure, speech-frequency currents pass to the moving coil C_1 through a condenser C and coil L. The steady plate current is diverted through a coil L_1 and passes through a special winding W



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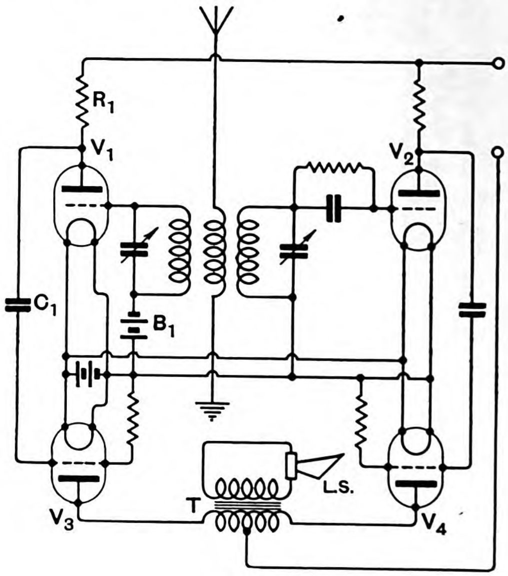
provided in addition to the ordinary field winding F. The whole filter unit is incorporated in the loud-speaker casing.

Patent issued to H. Green and Celebritone, Ltd.

RECEIVING CIRCUITS.

Application date, 24th January, 1928. No. 310764.

The aerial input is applied simultaneously to two detector valves V_1, V_2. The former V_1 is adjusted by means of a grid-bias battery so as to give bottom-bend anode rectification, whilst the latter V_2 operates on grid-leak rectification. The anode current in V_1 therefore increases whilst that in V_2 decreases, so that the two sets of detected oscillations are 180° out of phase. The output from V_1 is applied through the resistance R_1 and coupling



No. 310764.

condenser C_1 to a low-frequency amplifier V_3, whilst V_2 is similarly coupled to the amplifier V_4. The two currents are transferred cumulatively across a centre-tapped transformer T to the loud-speaker LS.

Patent issued to The Edison Swan Electric Co., Ltd., and L. H. Soundy.

MEASURING DISTANCES BY RADIO.

Convention date (France), 15th December, 1927. No. 302602.

The distance between two wireless stations may be ascertained by causing an outgoing train of waves from the first station to be automatically retransmitted from the second station back to the first, and so on, the periodic note set up at the first station being a function of the distance separating the two.

According to the present invention, an oscillating valve is interposed between the transmitting and receiving circuits at the first or active station, and serves to interrupt or modulate the outgoing wavelength at a definite frequency, the receiving circuit being rendered sensitive only during those intervals when the transmitter is quiescent. The distance between the local or active station and a distant or passive station is then determined by adjusting the frequency of the oscillating valve or modulator until maximum reception of the re-transmitted wave is obtained. This period corresponds to the time taken for a wave train to reach the distant station and return.

Patent issued to A. Koulikoff.

INDIRECTLY HEATED VALVES.

Application date, 13th December, 1927. *No.* 307857.

An indirectly heated valve comprises a carbon heating-filament wound on a porcelain rod mounted inside a central nickel tube which forms the cathode or electron-emitter. The surface of the latter is comparatively large and dissipates a considerable amount of heat. To prevent the heat from being trapped in the space between the cathode and anode, and so possibly raising the control grid to a temperature at which it may also emit electrons, the anode is so shaped or provided with openings or gaps as to allow the heat to escape freely. At the same time in order to prevent the electron stream from passing through the "open" anode, and so charging-up the glass wall of the bulb, a further perforated electrode is located concentric with but outside the anode, and is maintained at zero potential by a connection to the cathode.

Patent issued to E. Y. Robinson.

BEAM AERIALS.

Application date, 11th February, 1928. *No.* 311449.

Each radiating conductor in a multiple system of the Beam type is associated with a reflector unit consisting of a number of conductors so arranged as to have a ratio of inductance to radiation-resistance less than that of a single conductor. It is then found that over a band of frequencies extending on each side of the fundamental frequency of the reflector, the induced currents are larger and more nearly in phase than is the case with a single-wire reflector. The improved aerial system as a whole can therefore be operated over a wider band of frequencies than usual.

Patent issued to C. S. Franklin.

LOW-FREQUENCY AMPLIFIERS.

Application date, 16th February, 1928. *No.* 311466.

An amplifier, particularly adapted for undistorted telephony over long cables, comprises one or more thermionic valves or photo-electric cells provided with means for neutralising inter-electrode capacity effects, and an inter-valve coupling circuit so designed that the frequency characteristic of the amplifier as a whole is a rising curve which automatically compensates for the falling-off in the frequency values due to attenuation and similar losses along the carrier line or cable.

Patent issued to W. S. Smith and N. W. McLachlan.

SOUND REPRODUCERS.

Application date, 23rd November, 1927. *No.* 311826.

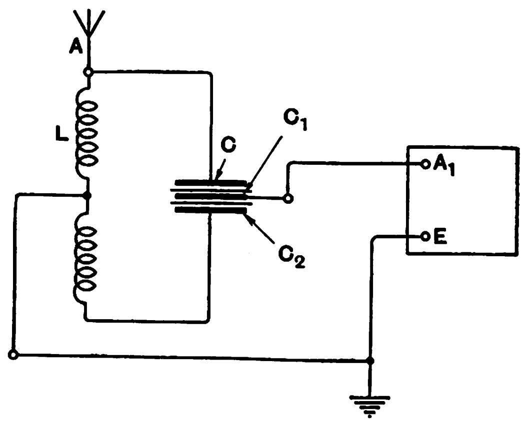
The main feature of the invention lies in the use, in an electro-dynamic microphone or loud-speaker, of a sound-responsive member in the form of a bag, substantially closed and forming or communicating with a gaseous reservoir. The bag functions as a collapsible diaphragm, free around the periphery yet substantially sound-tight. A conducting winding is bonded with the bag, and set between the poles of a magnet, an air space being left between the bag and the magnet, and between the bag and a resonant bronze backing. The gaseous reservoir contains cotton-wool to damp the air column. The bag may be folded into parallel layers and may be combined with ribs, stays, or honeycombs arranged in series or parallel formation.

Patent issued to A. F. Sykes.

INTERFERENCE ELIMINATORS.

Application date, 13th April, 1928. *No.* 311526.

A unit for improving selectivity in wireless reception consists of an inductance coil L shunted by a three-plate condenser C, C_1, C_2. The centre point of the coil L is connected to earth E, whilst the two outer ends are joined to the fixed plates C, C_2 of the condenser. The centre plate C_1, which may be protected by mica plates, is mounted on a screwed spindle for adjustment and is connected to the aerial terminal A_1 on the set. The arrangement permits the effective length of an outside aerial A to be varied at will within wide limits, thus increasing selectivity. At the same time undesired signals picked up on the earth lead from the set



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can be fed to the input in opposition to those picked up by the aerial proper, and so balanced out.

Patent issued to N. P. Hinton and Metropolitan Vickers Electrical Co., Ltd.

PIEZO-CONTROLLED VALVE OSCILLATORS.

Convention date (Germany), 2nd December, 1927. *No.* 301510.

The direct control by a piezo-electric crystal of a valve oscillator taking an input of more than a few watts presents difficulty owing to the tendency of the crystal to fracture under comparatively small loads. To overcome this defect two or more crystals of the same natural frequency are connected in series across the plate and filament so as to divide up the total control voltage in equal shares between them.

Patent issued to Lorenz A.G.

PICTURE TRANSMISSION SYSTEMS.

Convention date (*U.S.A.*), *25th November*, 1927. *No.* 301327.

In order to prevent "streakiness" and to secure a good half-tone effect in reception, the picture is scanned at the transmitting end, first in one direction, and then at a later period in a different direction, at an angle to the first. In this way each point of the picture is traversed by the light-ray and recorded twice, with an intervening period of time, the picture meantime being continuously advanced relatively to the scanning device. The resulting half-tone effect is thus made up of a series of separate lines woven in and out.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

DIRECTIVE AERIAL SYSTEMS.

Application date, *26th January*, 1928. *No.* 310451.

A concentrated beam of radiation, directed upwards at an angle to the horizontal, is obtained from a bank of antennæ spaced apart by a fraction of a wavelength. Each antenna consists of a single wire with an intermediate portion folded back on itself so as to suppress radiation from that part, leaving the upper and lower portions of the wire the only effective radiating elements. Both the effective and non-effective portions are made slightly longer than one wavelength, whereby the current in the upper part lags behind that in the lower, so as to give the emitted beam an upward trend.

Patent issued to C. S. Franklin.

THERMIONIC OSCILLATION GENERATORS.

Application date, *3rd February*, 1928. *No.* 310915.

An oscillation generator consists of a four-electrode valve to which suitable potentials are applied to cause it to operate over the falling or negative-resistance portion of its characteristic curve. The output circuit comprises two differently tuned oscillatory circuits, one of a radio and the other of audio frequency. The system generates two corresponding frequencies, one of which automatically modulates the other.

Patent issued to N. W. McLachlan.

LOUD SPEAKERS.

Application date, *16th April*, 1928. *No.* 311071.

A flat or conical diaphragm, propelled at its centre and flexibly supported around its periphery, is maintained in correct centring by means of a number of arms each secured at one end to the diaphragm and at the other to a suitable base. The arms are inclined to the axis of the diaphragm so as to apply a slight torsion or twist simultaneously with the normal plunger movement of the diaphragm. This is stated to allow greater freedom of vibration, whilst at the same time ensuring that the diaphragm always returns to its normal position.

Patent issued to Graham Amplion, Ltd., and P. K. Turner.

COOLING POWER GENERATORS.

Convention date (*U.S.A.*), *17th March*, 1927. *No.* 287463.

In valve generators of large power it is usual to apply cooling-water to the anode. As the water is at earth potential and has some conductivity, it will constitute a high-resistance shunt and may dissipate some of the radio-frequency energy. To avoid this source of loss, the inductance coils of the output circuit are made tubular and carry the cooling fluid. The fluid is fed into and leaves the inductance pipes at points which are at zero alternating potential, and is therefore only shunted across the D.C. supply. The arrangement has the additional advantage of maintaining the inductance coils at a constant temperature, so as to prevent any fluctuation in wavelength caused by impedance changes due to heating.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

ALL-MAINS AMPLIFIER.

Application date, *8th February*, 1928. *No.* 311305.

The first valve is resistance-capacity coupled to the second, which in turn is transformer-coupled to a bank of four power valves, the filaments of which may be arranged either in series or parallel. The eliminator unit consists of one two-plate rectifier in series with a baretter for the filament supply, and two half-wave rectifiers for the high tension. One of the smoothing chokes in the filament supply is also utilised to energise the field-windings of a moving-coil speaker. A tapped resistance for use with D.C. mains is also incorporated in the same unit. Grid bias is derived from a resistance inserted in the negative lead of rectified high-tension circuit. Provision is made for switching-in an electric pick-up for gramophone reproduction.

Patent issued to L. G. H. Cantle.

SCREENED-GRID VALVES.

Application date, *30th November*, 1927. *No.* 310760. (*Patent of addition to* 192464.)

A screened-grid valve comprises a spherical-coiled wire cathode totally enclosed by a similarly shaped anode. Between the two are a pair of spherical grids, spaced away from each other, and from the anode and cathode. Two such units may be arranged within the same glass bulb, in which case the electrodes are made hemispherical in shape.

Patent issued to W. R. Bullimore.

TELEVISION APPARATUS.

Application date, *30th November*, 1927. *No.* 312406.

The rotating disc used in reception to distribute the light and shade intensities from a neon lamp or similar light source on to a viewing screen is fitted with lenses of short focal length, or a single short-focus lens is mounted closely adjacent to the exploring disc. The object is to limit the angular dispersion of the emerging rays of light, and thereby to secure a brighter image on the viewing screen.

Patent issued to J. L. Baird and Television, Ltd.

EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. OCTOBER, 1929. No. 73.

Editorial.

The Radio Exhibition at Olympia.

AT the time of writing the doors are open to the annual wireless exhibition organised by the Radio Manufacturers' Association of Great Britain. It is always of interest in connection with the annual show to observe what is the changing tendency in fashion or design of apparatus for broadcast reception. That fashions do change there can be no doubt, for at definite stages in the history of broadcasting some new product has gained for itself a reputation which has resulted in it being almost universally adopted amongst users of broadcast receiving apparatus. We have only to take one outstanding example and observe how the moving-coil loud speaker established itself within a short time and almost completely eclipsed the horn type of loud speaker which had been in vogue prior to its advent.

In looking round the Radio Show at Olympia this year the principal impression that one receives is that, due no doubt to the introduction of the Regional Scheme for distributing broadcasting in this country, manufacturers have turned their attention to increasing the selectivity of their receivers, for high-frequency stages employing screen-grid valves are much more in evidence than they have been previously. The tendency, too, is towards an increase in the number of receivers which are designed to operate direct from the electric supply mains, and there seems little doubt that within a very short while the change-over from battery-operated to mains-operated sets will become very general. In this country we are, of course, largely handicapped because of the differences in the nature of the supply all over the country, but the efforts which are being made in the direction of standardising the voltage and periodicity of A.C. supply mains will contribute very largely to popularising the mains-operated broadcast receiver.

A recent visit to the Berlin Radio Exhibition left us with the impression that in our own country we are far ahead in the matter of actual circuit design of our receiving sets, but we could learn some useful lessons from the German manufacturer in regard to quantity production. Prices generally at the Berlin Show were lower than prices at our own exhibition, our better-class receivers being, in fact, little cheaper than they were last year. This is probably the direct result of the necessity which has arisen for greater selectivity and the use of screen-grid valves requiring more elaborate screening than was called for in earlier designs. Our designers have found it possible, in most cases, to dispense with one valve and yet get results at least equivalent to what was obtainable last year because of the increased efficiency of valves and the associated circuits. It is questionable whether, for commercial production, it is worth while to attempt to cut down the number of valves to a minimum and increase the efficiency of H.F. circuits, because by so doing the care needed in screening and other details becomes so important that from a manufacturing point of view it may entirely offset any saving effected.

Experimental Transmitting and Receiving Apparatus for Ultra Short Waves.

By R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E., and J. S. McPetrie, B.Sc. (National Physical Laboratory).

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Part I.

Retrospective and Summary of Other Work.

THE study of the behaviour of electromagnetic waves which have travelled through the ionised regions of the earth's atmosphere has attracted considerable attention during the past few years among investigators in the radio field. A discussion which took place at the Royal Society in March, 1926, made it evident that the use of electromagnetic waves within the band of wavelengths normally employed for radio communication provided a very powerful means of investigating the electrical state of the upper atmosphere. In the course of this discussion it was suggested by Smith-Rose and Barfield (1) * that some useful results might be obtained by carrying out experiments with a concentrated beam of radiation projected at definite angles of incidence towards the upper atmosphere and by locating and investigating the deflected waves on their return to the earth's surface.

If such experiments are to be made on normal wavelengths above say, 15 metres, it is evident that practical considerations necessitate the use of special aerial circuit arrangements at the transmitting station in order to obtain reasonable concentration of the radiation at various angles of elevation to the earth's surface. It was with the object of obtaining data for the design of such special aerial circuits that Wilmotte began the investigation of the characteristics of transmitting aerials a year or two ago. By confirming experimentally the theoretical distribution of current in an aerial system, Wilmotte (2) has been able to calculate the polar radiation diagrams of certain typical transmitting aerials; and experiments are now in progress to confirm these calculations by experimental measurements made in the air with appreciable angles of elevation at the transmitter. This investigation has shown, however, that this method of studying the upper atmosphere imposes certain restrictions on the angle of elevation at which a reasonable concentration of the radiation can be obtained, particularly when the space available at the transmitting station is restricted.

The alternative method of attacking the problem is to employ a comparatively simple aerial arrangement in conjunction with a reflecting system to attain at least two-dimensional concentration of the emitted radiation. The simplest form which this system can take is that of a half-wave Hertzian rod situated at the focal line of a cylindrical parabolic reflector, but other arrangements are not outside the scope of the investigation. In order that the beam from such a source may be oriented and elevated as desired, it is evident that somewhat severe limitations will be imposed on the maximum wavelength which may be employed. It was realised at the outset that the mechanical design of such an arrangement would become simpler as the wavelength was reduced, so the initial experiments had for their object the study of the technique of working on wavelengths of only a few metres. At the commencement of this investigation some two years ago there was little, if any, published information on the generation, transmission and reception of wireless waves of lengths below about ten metres. In the interval a few workers have been experimenting in this region, usually with a more commercial end in view than that of the present authors and a brief summary of the published accounts of this work will be given in the next section.

(a) Damped Oscillations.

In the production of electromagnetic waves of two or three metres in length, Heinrich Hertz (3) was probably the first with his classical experiments carried out

* The figures in brackets refer to the Bibliography pp. 541 and 542.

in the years 1880–90. In this work and in that of his successors who worked on the problem and demonstrated the various properties of the waves, spark discharge oscillators were employed which gave intermittent groups of damped oscillations. Following the application of this work to practical wireless communication, the spark transmitter was developed to a high degree on the longer wavelengths of from 100 metres upwards. One of the most recent applications of damped waves of a few metres wavelength is the rotating beam transmitter described by Franklin (4) in 1922. Using a wavelength of about 6 metres, a Hertzian rod transmitting aerial was located at the focal line of a cylindrical parabolic reflector, the whole system being rotated continuously to enable ships to determine wireless bearings. Of recent years, also, the spark transmitter has been developed as a means of generating extremely short waves in an attempt to link up the electric wave spectrum with that of the infra-red. Among the earliest workers in this field may be mentioned Nichols and Tear (5) who, with the aid of small Hertzian oscillators formed of tungsten cylinders 0.5 to 0.2 mm. in diameter and 5 to 0.2 mm. long, generated electromagnetic waves less than 1 mm. in wavelength and measured the resulting radiation with a radiometer type of receiver. Measurements were also made on an electromagnetic wave receiver of Rubens' and von Baeyer's infra-red rays as obtained from a quartz enclosed mercury arc. The range of electromagnetic waves obtainable in this region has been considerably extended by the work of Arkadiew (6) and Glagolewa-Arkadiewa (7), who generated oscillations by discharging a high-tension source through a uniform paste made of an intimate mixture of brass or aluminium filings and viscous mineral oil. Such "paste" oscillators give electromagnetic waves whose wavelength is chiefly dependent upon the size of the filings; and in Glagolewa-Arkadiewa's experiments the wavelengths varied from 0.082 mm. up to 5 cms., thus overlapping the Rubens infra-red spectrum on the one side and the oscillations of Nichols and Tear on the other side. M. Lewitzky (8) has also worked on similar lines, using as the oscillators small lead spheres about 0.8 mm. diameter stuck in Canada balsam. By this means he generated electric waves as short as 0.01 mm. and demonstrated their optical and heating properties with the aid of an ordinary diffraction grating and a sensitive thermo-junction.

Quite recently, Busse (9) claims to have generated some 50 watts of energy on wavelengths of the order of 30 cms. by using a quenched spark-gap oscillator. The primary high-frequency current is supplied by a half-kilowatt valve working on 960 metres, and the quenched gap is included in a closed short-circuit to which a dipole oscillator is coupled.

(b) Ionic or Electronic Oscillations.

After the classical work of Hertz and his successors in the production of damped waves of a few metres wavelength, a period of nearly thirty years elapsed before it became possible to produce, even on a laboratory scale, undamped oscillations of the very high frequency corresponding to this short wavelength. This phase of the science had, in fact, to await the practical development of the thermionic valve.

When considering generally the use of valves for the generation of oscillations of extremely high frequencies, it is evident that the design and construction of the valve will set an upper limit to the frequency obtainable. For if the appropriate electrodes of the valve be connected by wires of the shortest possible length, the limiting frequency is determined by the inductance of the loop so formed and the capacity between the electrodes. By the use of specially designed valves, several investigators have reduced the inter-electrode capacity to such an extent as to enable them to obtain oscillations of a frequency up to nearly 300 megacycles per second (corresponding to a wavelength of one metre).* If attempts are made to extend this process, a second limitation is soon reached, which is determined by the time of travel of the electrons from filament to anode inside the valve. Pfetscher (10) has investigated this point theoretically, and has shown that the lowest wavelength obtainable by the generation of oscillations in circuits by the use of valves and retro-

* *See*, for example, C. R. Englund, Bibliography, Ref. 34.

action is of the order of 1.2 m. (280 million cycles per second). Beyond this point it appears that an increase in frequncy of the oscillations obtainable from thermionic valves can only be brought about by utilising the resonance properties of the ionic or electronic motions inside the valve. The possibility of producing such ionic oscillations in thermionic valves was first described by Whiddington in 1919 (11). Employing a soft valve in his experiments, Whiddington obtained oscillations having a maximum frequency of 4×10^5 cycles per second with gaseous ions, but he indicated the possibility of increasing this to 4×10^8 by confining the oscillations to electrons alone.

The realisation of these higher frequencies was described shortly afterwards by Barkhausen and Kurz (12), who employed hard valves operating at high grid potentials and so obtained oscillations at a frequency of 3×10^8 cycles per second corresponding to a wavelength of one metre. The existence of the oscillations was detected by connecting a Lecher wire system between the grid and anode of the valve, and the frequency obtained was found to depend upon the valve filament current and the grid and anode voltages. Investigations on these lines were continued by Schrenk (13) and by Shaefer and Merzkirch (14) who extended the available frequency range to 10^9 cycles per second (corresponding to a wavelength of 0.3 metre). Schiebe (15) has found that a valve can produce this type of oscillation at two frequencies which are nearly but not quite in the ratio of 1 : 2. He has also confirmed the dependence of the frequency upon the valve dimensions and the applied voltages. More recently, Hollmann (16) has worked on this problem, and has succeeded in modulating the oscillations and so producing a radio-telephony transmitter operating on wavelengths of from 0.30 to 1.0 metre.

Nettleton (17) has made an extensive study of the characteristics of a valve when producing electronic oscillations of the type described above, and has shown that there is an appreciable negative current to the anode during the process. By studying the dependence of this anode current upon the grid voltage, electron current and gas pressure, it became apparent that the phenomenon was not purely electronic: in fact, a small amount of ionisation is necessary for the manifestation of oscillations which, together with the negative anode current, cease very suddenly at pressures of the order of 10^{-5} mm.

This appears to be somewhat in conflict with the previous work of Gill and Morrell (18*a* and 18*b*), who demonstrated and explained the possibility of obtaining oscillations in a gas-free tube as a direct result of the electronic motions between grid and anode, when the grid was at the higher potential. Gill and Morrell's experiments deal with wavelengths of from 2 to 6 metres and illustrate the dependence of the wavelength upon the grid and anode voltages and the filament heating current. In a later paper, Gill and Morrell (18*c*) describe the production of another type of oscillation arising from the secondary emission of electrons from the anode. More recently, Sahánek (19) has investigated both theoretically and experimentally the methods of obtaining the type of oscillations discussed above, and has established a common foundation for the different methods. Wechsung (20) has also studied the same type of oscillation produced with an applied A.C. instead of D.C. voltage; while Grechowa (21) has investigated the effect of working conditions upon the oscillations produced.

(c) Undamped Waves and their Applications.

Reverting to the more usual method of producing oscillations by the use of a three-electrode thermionic valve with retroactive coupling between its circuits, White (22) described in 1916 a circuit arrangement which gave satisfactory operation at 50 megacycles per second (*i.e.*, a wavelength of 6 metres). Three years later, Gutton and Touly (23) described experiments made with the ordinary type of triode in which the wavelength was reduced to 3 metres, and by the use of a special low-capacity type of valve this was lowered to 2 metres. These writers laid stress upon the fact that the oscillations were produced in the same manner as those of lower frequency, *i.e.*, by inductive retroaction between the external grid and anode circuits of the valve: they also indicated the advantages which continuous oscillations possessed over the intermittent damped oscillations for experimental research and measurement purposes.

The last-mentioned paper was followed by one by B. van der Pol, Jnr. (24), also in 1919, describing the production of waves down to 3.6 metres wavelength. In these experiments two tuned circuits were employed connected to the grid and anode of the valve respectively, but with no external retroaction between them. The maintenance of oscillations was thus dependent upon internal coupling by means of the grid-anode capacity of the valve. By the aid of these oscillations van der Pol measured resonance curves for a Lecher wire system and obtained a value for the logarithmic decrement of the system. In a paper published in 1920, Southworth (25*a* and 25*b*) made a brief analysis of the general form of the circuit of an oscillating valve, and drew attention to the necessity of substituting for "lumped" inductances circuits having distributed inductance and capacity if successful operation at wavelengths below 10 metres is to be obtained. With the inductance in the form of a rectangle, with a length of side of the order of 3 inches, wavelengths below 2 metres were obtained with ordinary receiving valves. Both van der Pol and Southworth remarked upon the pure sinusoidal nature of the oscillations obtained and the difficulty of detecting the presence of any harmonics. In a later paper Southworth (25*c*) described the generation of waves varying from 1.24 to 2.76 metres in wavelength, and the use of such waves for studying the dielectric constant of water. In this connection it is interesting to mention the earlier paper of Tear (26) describing the measurement of the optical constants of water, glycerin, methyl and ethyl alcohol for damped trains of electric waves, of wavelength from 0.4 mm. to 40 mm.

In 1924, Mesny (27*a*) described the results of investigations on short waves carried out in the French Laboratory for Military Radio Telegraphy under the direction of General Ferrié. Arising out of a previous study of the generation of polyphase oscillations at high frequency, Mesny has given particular attention to the balanced two-valve type of circuit which was described by Eccles (28) in 1919. With this arrangement wavelengths as short as 1.5 metres were attained with low-power transmitters, and experiments were carried out on the telephone modulation of such waves. Using the super-regenerative type of receiving circuit, satisfactory telephonic communication has been obtained over a distance of 280 kilometres between two mountain peaks in the Alps with a power supply of only 3 watts (27*b*). When the same experiment was attempted along flat ground, the distance of satisfactory transmission was reduced to 2 or 3 kilometres, thus illustrating the serious absorption effect of the earth for very short electromagnetic waves. Further tests on these lines have been described more recently by Ritz (29). Employing the same type of circuit, Gutton and Pierret (30) have isolated harmonics of the main oscillation and have thus succeeded in producing frequencies corresponding to wavelengths of the order of 0.35 metre.

An interesting extension of the symmetrical two-valve oscillating circuit discussed above was provided by Danilewsky (31), who used a single five-electrode (two grids and two anodes) valve with this circuit for generating oscillations of a few metres in wavelength.

Tykocinski-Tykociner (32) has described the development of low-power laboratory-type oscillators suitable for generating oscillations of frequencies from 50 to 100 million cycles per second (wavelengths 6 to 3 metres); and has used these for the study of antenna problems with the aid of scale models.

A good general account of the experimental investigation of the behaviour of transmitters and receivers on all wavelengths below 100 metres is given by Mesny (33) in a monograph published in 1927. In addition to a survey of the technique of the subject, this work discusses the existing knowledge of the propagation of wireless waves around the earth. As already mentioned, Englund (34) has investigated the short-wave limit of valve oscillators of the normal type, and has found this to be between 3.5 and 1.5 metres for ordinary commercial receiving valves. By means of a special valve a wavelength of 1.05 metres was reached.

Prominent among the more recent research on the subject of short-wave working, may be mentioned that carried out in Japan. Uda (35) has investigated in some detail the behaviour of antennæ and reflectors for use in beam transmission, while Yagi (36)

has carried out various experiments on wavelengths below 5 metres to show the effect of the earth in attenuating the waves, and of the directive properties of systems of inductively excited antennæ and reflector wires.

Okabe (37) also has applied the magnetron type of valve oscillator to the production of waves less than half a metre in length, and in a recent publication has discussed the relation of such oscillations to those of the Gill-Morrell and Barkhausen-Kurz type. In a more recent publication Žácek (38) has drawn attention to the fact that he described the use of the magnetron for the production of very short waves in 1922.

During the past year or so publication has been made of several researches conducted under the supervision of Professor Esau. In one paper, Cords (39) describes a detailed experimental study of the oscillating valve for wavelengths in the neighbourhood of 3 to 6 metres, and gives the results of the application of this work to a short-wave receiver using a single oscillating valve with critical control of retroaction. In a later paper, Wechsung (40) deals with the corresponding transmitting problems from both a theoretical and experimental viewpoint; and the results of this work are applied to the design of practical transmitters of from 150 to 2,000 watts rating, operating on wavelengths of 2.8 to 6 metres. Esau (41) has described the application of this apparatus to practical communication on wavelengths of the order of 3 metres. Tests gave good results with telephony transmission over ranges up to 130 kms., and freedom from atmospherics or other disturbances was observed.

Part II.

Analysis of Circuits Suitable for Short-wave Oscillators.

(a) Single-valve Circuits.

We may arrive at a general idea of the circuits suitable for work on short waves by a consideration of those commonly used on longer wavelengths. The usual method of making a valve oscillate at these wavelengths is to transfer energy from the anode circuit to the grid circuit of the valve until at least as much energy is taken from the anode current supply as that lost in the valve and its attendant circuits. Figs. 1 and 2 represent two circuits typical of those popular in transmitters some years ago.* In these two transmitters the necessary energy required from the anode battery is obtained by mutual induction between the

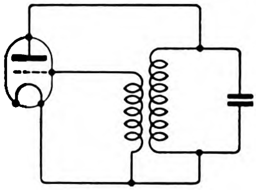

Fig. 1.

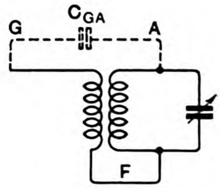

Fig 1a.

anode and grid coils. These two circuits are closely similar although in Fig. 1 we have the tuned circuit between the anode and filament, while in Fig. 2 it is between the grid and filament.

These two circuits may be combined to make that of Fig. 3, in which both the grid and anode coils are tuned. This circuit is redrawn in a more suitable form in Fig. 4. Now, if the inductance of the grid coil L_1 is equal to the anode inductance L_2 and the capacities of C_1 and C_2 are also equal, the natural frequency of the grid and anode circuits is the same. Moreover, the natural frequency of the circuit $L_1\ L_2\ C_2\ C_1$ is also the same as that of $L_1\ C_1$ and $L_2\ C_2$. This means that as far as the oscillatory current is concerned, we may omit the connection between the common point of the inductances $L_1\ L_2$ and the condensers $C_1\ C_2$ without altering the constants of the circuit. Fig. 5 shows such a circuit. In this we can obviously replace the double condenser $C_1\ C_2$ by a single one C as shown in Fig. 6. This is commonly known as the Hartley circuit, but in accordance with the footnote below we shall refer to it as circuit number 6. If desired, the connection between the filament and the centre point of the coil may be omitted as shown in

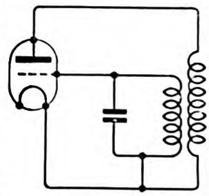

Fig. 2.

* In order to avoid ambiguity and the question of priority entailed when a circuit is named after someone intimately connected with it, we shall refer to all circuits by the number of the figure under which they appear in this paper.

Fig. 6(a); by this means, the oscillation is left free to locate its nodal point at or near the centre of the inductance. In some cases at short wavelengths this may be a definite advantage, since it is unnecessary to find the exact electrical centre of the inductance, which is the only point that should be held at the filament potential.

We may derive another circuit from Fig. 4 by omitting (as in Fig. 5) the connection between the centre point of $L_1 L_2$ and $C_1 C_2$, while leaving the filament connected to the common point of the condensers. This circuit, which is often called the Colpitts circuit, is shown in Fig. 7.

We have so far neglected the method of power supply to the valve. It is evident that in circuit No. 7, the only method of high-tension supply is through a choke coil to the anode: the choke is required in this case in order to prevent leakage of high-frequency current into the high-tension

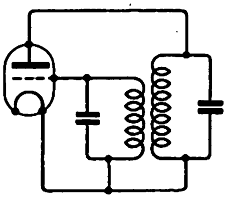

Fig. 3.

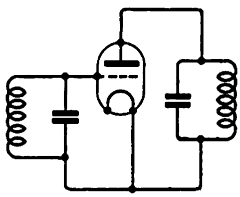

Fig 3a.

supply. There are two methods by which power may be supplied to circuit No. 6. These are shown in Figs. 8 and 9 and are usually known as the shunt and series-feed systems respectively. This nomenclature is due to the fact that in circuit No. 8 the high-tension supply is in parallel with the oscillatory circuit, while in Fig. 9 these are in series. It is necessary in most of the circuits dealt with to insert a blocking condenser in series with the grid in order to render this independent of the direct-current H.T. supply. In the case of the circuit in Fig. 9, it will be noted that the high-tension supply has been inserted in the connection between the filament and the centre point of the inductance. This, together with the insertion of the blocking condenser, isolates the grid for D.C. voltages. A suitable leak R, must therefore be inserted as shown between the grid and filament in Fig. 9.

There may be a small difference in the behaviour of the above oscillators at long and short wavelengths. At medium and long wavelengths the coupling between the grid and anode coils is predominantly

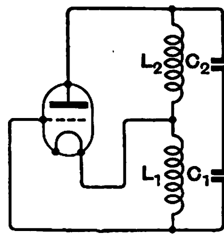

Fig. 4.5

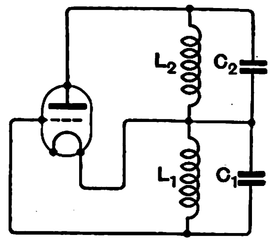

Fig. 5.4

inductive. On shorter wavelengths, however, the electrostatic couplings between the coils and the valve electrodes become important and at very high frequencies may exceed the magnetic coupling. Care must, therefore, be taken in the layout for high frequencies as the electrostatic and magnetic couplings are usually of opposite sign.

It is the small capacity inside the valve between the grid and filament which determines the suitability or otherwise of the above circuits for work on short waves. If we take circuit No. 1 its equivalent circuit diagram may be drawn as in Fig. 1 (*a*), where C_{GA} represents the capacity between the grid and anode of the valve. A little consideration will show that in the condition for oscillation the condenser C_{GA} acts against the mutual induction between the grid and

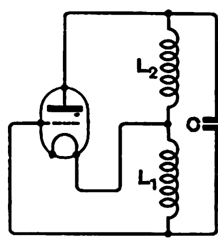

Fig. 6.

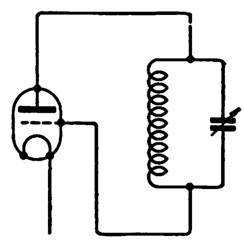

Fig. 6a.

anode coils. Suppose, for example, the grid G becomes temporarily of lower potential than its steady D.C. value. A pulse of current will flow from F to G. The resistance of the valve will increase and therefore diminish the anode current with consequent rise in anode voltage. The mutual in-

duction between the grid and anode coils should be such as to assist this action. When the grid G increases in potential, therefore, the anode voltage should fall. The capacity C_{GA} tends to stop this action, and in doing so decreases the amplitude of the oscillation. The effect of this capacity, however, is small, except at very high frequencies, and we are left with the result that circuits Nos. 1, 2 or 3 are suitable for work on medium and long waves, but unsuitable for the shorter wavelengths, say, below 100 metres. Incidentally, we thus see the possibility of deriving another generating circuit from Fig. 3, in which the inductive coupling between the tuned anode and grid circuits is replaced by the capacity coupling between the valve electrodes as in Fig. 3 (*a*).

For alternating current conditions the circuits 7, 8 and 9 deduced from the unsymmetrical circuits 1 and 2 are all symmetrical about the D.C. supply, and in each the grid-to-plate capacity is balanced by another condenser at the opposite end of the oscillatory circuit. This may be seen by considering Fig. 8 (*a*), which is the equivalent diagram of circuit No. 8. The input supply and output in this circuit are at opposite corners of a bridge circuit. This arrangement has been found advantageous in short-wave oscillators and has led automatically from the asymmetrical parent circuits Nos. 1 and 2, suitable for long and medium wavelengths, to their symmetrical derivatives Nos. 7, 8 and 9. In actual practice the condenser PA is greater than GP in order not only to neutralise the anode-grid capacity, but also to provide reaction of the proper sign between the anode and the oscillatory circuit.

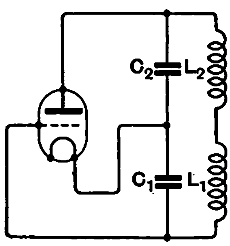

Fig. 7.

The single-valve circuits, given in Figs. 7, 8 and 9 can be made to oscillate at very short wavelengths by a careful selection of the inductance and condenser and adjustment of the D.C. supply circuits. While in most cases smooth and continuous alteration of wavelengths can be obtained by a variation of the tuning condenser, it is sometimes found that the oscillation frequency suddenly jumps from one value to another and higher value not harmonically related to the first. This effect is probably due to the fact that the connecting leads to the tuned circuit are comparable in reactance to the inductance, and that the system really comprises two circuits coupled

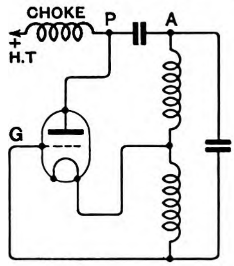

Fig. 8.

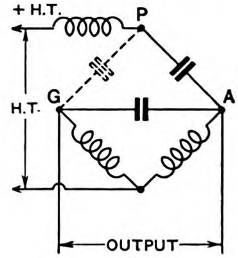

Fig. 8a.

by the main tuning condenser and having two degrees of freedom. For instance, in Fig. 9(a) we have the two tuned circuits C_v C_1 L_1 C_3 L_2 C_2 and C_3 L_3 coupled by the common condenser C_3. The validity of this explanation is supported by the fact that the value of the second or higher frequency referred to above is dependent upon the capacity of any coupling condenser inserted in the connecting leads.

(b) Two-valve Circuits.

The full lines in Fig. 10 represent circuit No. 9. A little consideration will show that we may add another valve as shown by the dotted lines without upsetting the bridge arrangement of circuit No. 9. The valve shown by dotted lines forms with the main oscillatory circuit another No. 9 circuit.

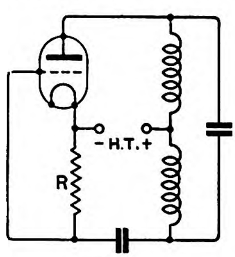

Fig. 9.

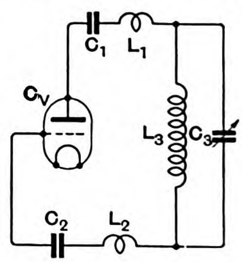

Fig. 9a.

Provided they have similar characteristics, both valves will tend to oscillate and it will be seen that they are so connected that they will mutually help one another to oscillate

in opposite phase. This oscillator circuit was first described by Eccles and Jordan* (28). In this R_1 and R_2 are the grid leaks fixing the D.C. potentials of the two grids. Fig. 10 (*a*) represents the equivalent circuit diagram of circuit No. 10. It will be seen that the input and output are again connected across opposite corners of the bridge. The circuit will obviously oscillate when R_1 and R_2 in series are replaced by any circuit which has a high impedance at the frequency of the oscillator. For example, R_1 and R_2 may be replaced by chokes, the D.C. potential of the grids being fixed by a suitable resistance in the common lead from the filament to the common point of R_1 and R_2. Another method of having a high impedance between the two grids is to replace R_1 and R_2 by a tuned circuit, as shown in Fig. 10 (*b*), which is another of the two-valve balanced circuits described by Eccles and Jordan (*loc. cit.*). The connection to the filament in this case is made to the middle point of the inductance just as it was in Fig. 10 to the centre of R_1 and R_2.

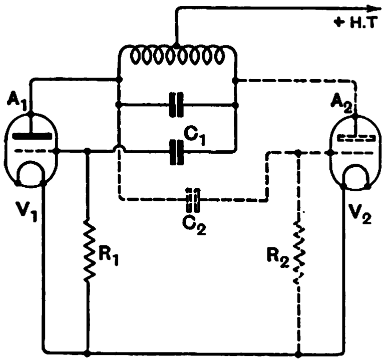

Fig. 10.

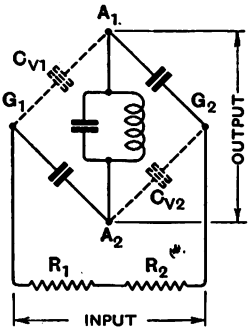

Fig. 10a.

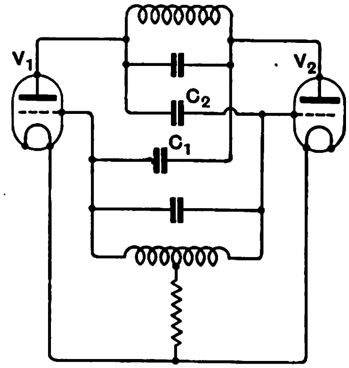

Fig. 10b.

In the double valve oscillator of Fig. 10 the condensers C_1 and C_2 act as retroaction condensers from the anode of one valve to the grid of the other. In circuit 10 (*b*), however, these condensers are not required as the mutual induction between the anode and grid coils may be made to provide the necessary retroaction. The diagram of such a circuit is given in Fig. 11. Analytically this circuit is closely analogous to that of Fig. 10 as the mutual induction between the anode and grid coils may be represented approximately by capacities between opposite ends of the two coils.

A simple explanation of the action taking place in such an oscillator as No. 11 may now be given. A slight modification will allow the explanation to hold for any of the double valve oscillators described above. Suppose some small disturbance in the circuit of oscillator No. 11 causes the potential of the anode of the valve V_1 to drop below that of the positive terminal of the high-tension supply. A pulse of current will pass from O to A_1 in the anode coil. The mutual induction between the anode and grid coils may be made of such sign as to make the current from O to A_1 induce a current in the grid coil from G_2 to G_1. This current from G_2 to G_1 raises the potential of G_1 and lowers that of G_2. The fall in potential of G_2 increases the resistance of the valve V_2 and the anode current through V_2 will diminish, with the result that the potential of its anode A_2 will rise. Thus, the potentials of the anode A_2 and the grid G_1 are at greater than their D.C. potentials, while the anode A_1 and the grid G_2 are at lower potentials. The two valves, therefore, are in a condition for oscillation provided enough energy is supplied by the mutual induction from the

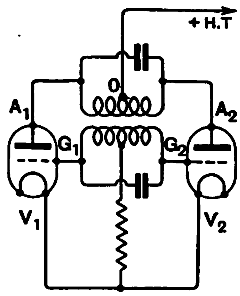

Fig. 11.

* W. H. Eccles and T. W. Jordan: "A Method of Using Two Triode Valves in Parallel for Generating Oscillations," *Radio Review*, 1919, Vol. 1, pp. 80–83.

anode coil to the grid coil to balance the loss in the latter circuit. The valves are in opposite phase as regards the oscillation and may be regarded as giving a pulse alternately to the oscillatory circuit.

(c) Practical Analysis of the Above Circuits.

The circuits described above are equally suitable for large- or small-power oscillators. The following practical analysis will apply more particularly to small-power oscillators using ordinary receiving valves.

It has been shown that there is a close connection between all the circuits and, as such, certain results apply to them all. For wavelengths in the region of about 10 metres a centre-tapped coil can most conveniently be made by a two-turn coil with a diameter of about 6 inches. The radiation from the oscillator decreases with the smaller coil but the two turns bring the centre-tap to a convenient position. No centre-tapped coil is required in circuit No. 7 and in this case the coil may be a single turn 10 inches in diameter. The size of the tuning condenser varies with the range of wavelengths required for each coil, but it should not be larger than $100\mu\mu F$. The same capacity is suitable for the coupling condensers in circuits Nos. 8 and 10 and the grid condenser in No. 9.

Circuit No. 8 is suitable for use with low impedance valves as the high-tension supply is shunted across the oscillatory circuit. A choke is necessary in the anode lead to increase the impedance across the high-tension battery. Very little knowledge is available as to the behaviour of chokes at very high frequencies. A design used by us consists of from 100 to 150 turns of No. 47 S.W.G. copper wire wound uniformly on a 3-inch ebonite or American whitewood former 1 inch in diameter. The chief advantages of circuit No. 8 are that it is convenient to couple it to an amplifier and that there is no D.C. voltage on the coil.

In circuit No. 9 the high tension is connected to the centre of the oscillating coil. There is no oscillating potential at this point so that no choke is required to prevent high-frequency leakage through the high-tension supply. A high-impedance valve may be used with this circuit as the high-tension supply is no longer directly across the oscillatory circuit. A grid leak and condenser are required. Part of the capacity of this condenser balances the grid-anode capacity and the remaining capacity acts as a reaction condenser. The maximum capacity of this condenser should be about $100\mu\mu F$. The combination of grid leak and condenser may give rise to squegging, while another disadvantage of this circuit is that the coil is at the high-tension voltage.

Both terminals of the tuning condenser in the above two circuits are at oscillating potentials. Care must therefore be taken to minimise hand-capacity effects when tuning. A double condenser such as is used in circuit No. 7 would do away with this disadvantage as the centre of the double condenser is a point of non-oscillating potential. If we use a double condenser we may tap either the centre point of the coil or the condenser. The absence of a centre connection on the coil is particularly suitable in directional coil transmitters or receivers. This point will be noted later.

The two-valve two-coil oscillator circuit No. 11 has the disadvantage that there are two circuits to tune and that it is difficult to vary the coupling between the grid and anode coils when working on short wavelengths. At very high frequencies the electrostatic coupling between the two coils may become important, and this coupling is of opposite sign to that intentionally introduced by the magnetic induction. Circuit No. 10, on the other hand, requires only one circuit to be tuned. The capacity coupling between the anode and grid circuits in this case is particularly easy to vary by using variable condensers. This circuit, being equivalent to two circuits of type No. 9 has the same disadvantages, namely, the centre-tapped coil and the possibility of squegging.

In all the double-valve circuits the valves must be chosen carefully as the efficiency of such oscillators depends to a large extent on the similarity of the characteristics of the two valves. It is also advisable to have a separate filament current ammeter for each valve and to balance the filament currents before connecting up the high tension supply. In most cases the setting of the filament currents to obtain oscillations at the highest frequencies is fairly critical.

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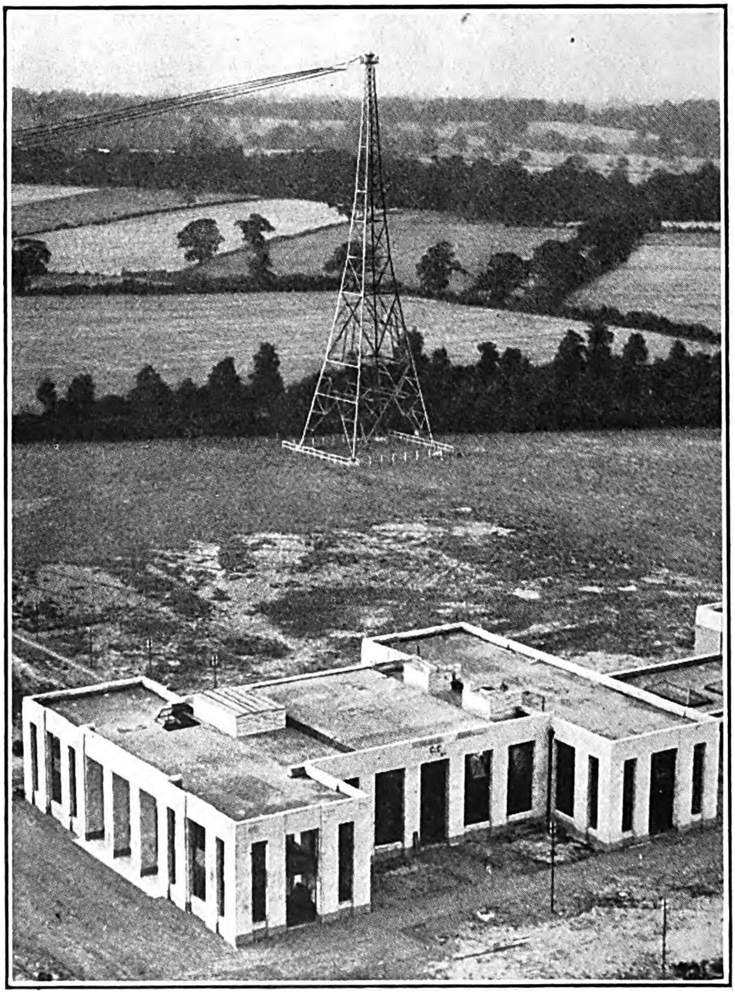
(*To be concluded.*)

Brookman's Park Transmitter.



The First Two-Programme Regional Station.

THE accompanying illustration is a photograph taken from the top of one of the masts of the new London Broadcasting station near Potter's Bar.

The station is the first of its type designed to operate on two wavelengths and transmit alternative programmes under the Regional Scheme. Each of the two transmitters normally delivers 30 kw. to the aerial, and it is anticipated that under working conditions approximately full power will be used. Test transmissions on one wavelength have already commenced outside the normal broadcasting hours.

The station is connected to the Studios at Savoy Hill by underground cables and provision is made so that in the event of line failure wireless reception from the Daventry station is possible as an alternative source for supplying the programmes. The masts carrying the aerials are 200 ft. high; it is understood that in the design of the station the B.B.C. engineers would have preferred to have been able to increase this height but had to conform to Government restrictions. The general design of the building is particularly attractive and, as the photograph shows, the architecture is severe and unusual.

The circuit adopted is similar to that of 5GB at Daventry.

Notes on Standard Inductances for Wavemeters and Other Radio Frequency Purposes.

By W. H. F. Griffiths, F.Inst.P., A.M.I.E.E., Mem.I.R.E.

SUMMARY.—In this article are given methods of constructing inductances with a view to the elimination of sources of inconstancy of sub-standard wavemeter calibration which are attributable to these components of simple resonant circuits. Such sources of inconstancy have hitherto been unimportant but may now become appreciable owing to the reduction of other sources of inconstancy by recent improvements in variable condenser design.

In addition to inconstancy due to age, lack of robustness, and temperature-coefficient, that due to changes of self-capacity and effective resistance with variation of humidity is considered.

PRECISE standards of self and mutual inductance have for many years been specially constructed for use in alternating current determinations at audio-frequencies. Such standards have been designed to have a high degree of geometrical constancy and a very low temperature-coefficient of inductance, but the materials from which their formers are constructed are usually of sufficiently high power factor to preclude their use at radio-frequencies even if all other characteristics of their design were suitable for this purpose.

Moreover such precise standards have not been necessary hitherto in radio-frequency determinations (particularly in the measurement of wavelength) since the air condensers, either variable or fixed, with which inductances are associated in sub-standard wavemeters of the simple resonant circuit type are invariably the limiting factors in the constancy of the natural frequency of such a circuit. Small changes in the geometry of an ordinary condenser are of much greater importance than are changes of similar magnitude in the case of an inductance.

Recently, however, since standards of frequency such as fork-controlled multi-vibrator wavemeters have been available and since wavelength determinations have to be more precisely effected due to the fact that the wavebands commercially available have naturally become more and more crowded, attempts have been made to design variable air condensers of great permanency of value and freedom from temperature-coefficient. Such a condenser has been described in this journal by the author.*

* *E.W. & W.E.*, January, February and May, 1928; January and February, 1929.

With this advance in condenser design it is thought that the construction of sub-standard wavemeter inductances should receive attention with a view to improving their permanence of value and freedom from temperature coefficient. Such improvements must, of course, be effected without impairing the time constant of the coil.

Ordinary single-layered coils wound on ebonite cylindrical formers are unstable when raised to fairly high temperatures, since ebonite upon cooling does not necessarily return to its original form after being heated, especially if the temperature change takes place while the material is stressed in any way such as by being bound with turns of copper wire which is expanding to a much smaller extent than the insulator. If the former is constructed from a loaded ebonite† the coil is more stable, but it will still have a fairly high (though more definite) temperature-coefficient of inductance, and the copper winding will, upon cooling after a rise in temperature, tend to become slack due to its having been stretched by the greater expansion of the former. The temperature-coefficient of inductance of such a coil is approximately equal to that of the linear expansion of the insulator from which its former is constructed, and it will be seen later that this statement is also true of multi-layered coils whose formers are constructed throughout from one insulating material only.

In view of these uncertainties, the author

† Ebonite loaded with minerals which harden the material and usually impart a distinctive colour. The electrical properties of a loaded ebonite are not quite as good as those of true ebonite, but certain of its mechanical properties are better. A description of a particular loaded ebonite known as Keramot is given later in the article.

has recently designed coils of the single-layered helix and multi-layered helix type, the formers for which may be made from ordinary easily worked insulating materials, each of which has a fairly high temperature-coefficient of linear expansion. The general principle‡ followed is that of constructing a

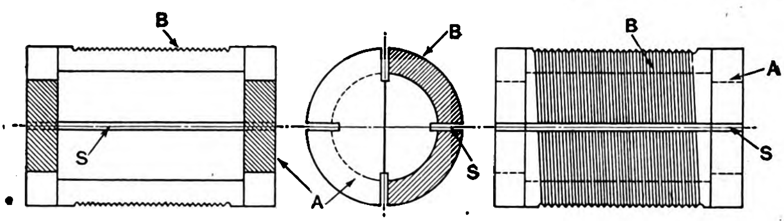


Fig. 1.

former from two insulating materials *A* and *B*, having *different* temperature-coefficients of linear expansion and different phase angles. The material *A* determining the mean diameter of the coil is selected to be of a very strong and permanent nature (usually such materials have a large power factor, so that electric fields must be kept from passing through them), and to have a temperature-coefficient of linear expansion equal to, or of the same order as, that of the conductor with which the coil is to be wound, so that the turns will not slacken or tighten on the formers with changes in temperature.

The material *B* on which the conductor is actually wound (usually in grooves or slots) is selected to have a lower power factor than that of *A*, in order that the dielectric loss due to the field between adjacent turns shall be small, and also to have a temperature-coefficient of linear expansion just sufficiently greater than that of the insulating material *A*, by which the mean diameter of the winding is determined so that the variation of inductance value due to the linear expansion of the former in an axial direction exactly compensates for the variation (of opposite sign) due to the area expansion of a mean turn due to the thermal changes in material *A*. In coils designed on this principle care must, of course, be taken to ensure that their diametrical dimensions are not in any way determined by the *B* material, which should be free to follow the expansions and contractions of the *A* material in all dimensions in a plane normal to the axis of the coil.

‡ Patent application made by H. W. Sullivan, Ltd., and the author.

The Construction of Compensating Formers.

In Figs. 1 and 2 is shown one method of former construction suitable for a single-layer helix. A stout walled tube "B" of ebonite or good low power factor loaded ebonite is reinforced at its ends by stout end cheeks "A" of Bakelite, which has a temperature-coefficient of linear expansion of the same order as that of copper. In order that the diameter of the winding shall be unaffected by the thermal changes of the tube, the circumferential continuity of the latter is destroyed by a number of radial saw-cuts *S* in the periphery of the coil.

One of the reasons for the choice of Bakelite for the *A* material is, as has been stated above, the closeness of its temperature-coefficient of expansion to that of copper, and it is fortunate that this is the case because of

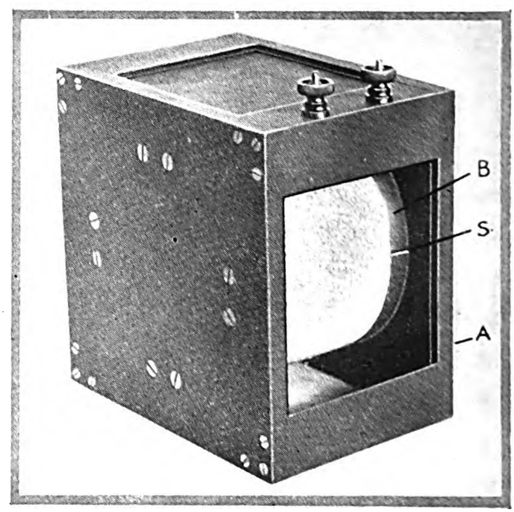


Fig. 2.

the mechanical suitability of this insulator for the framework of former constructions. A tabulation giving linear expansion co-efficients of a few of the most practicable

insulating materials for former construction will be found below, and it will be seen that the difference between the temperature-coefficients of Bakelite and copper (17×10^{-6}) is only 7×10^{-6} per degree centigrade,* a difference which would only produce a very small stretching of the conductor even were the temperature of the coil to be raised through, say, 30° C. In the case of a coil having a winding of silk-insulated wire such a dimensional difference would probably be taken up without stretching by a cushioning action of the wire covering and is therefore hardly worth considering. The relative linear dimensional changes with temperature of ebonite and copper are, however, seven times as great and cannot be neglected even for small changes of temperature, ebonite therefore being most unsuitable for use as an *A* material.

TABULATION.

Material.	Temperature-coefficient of Linear Expansion per Degree Centigrade.	Order of Power Factor.
Silica-quartz ..	1×10^{-6}	0.0002
Pyrex..	3×10^{-6}	0.005
Micalex	9×10^{-6}	0.0015
Bakelite	24×10^{-6}	0.05
Loaded Ebonite (Keramot) ..	65×10^{-6}	0.01
Ebonite	70×10^{-6}	0.005
Copper	17×10^{-6}	—
Aluminium	23×10^{-6}	—

It is perhaps, interesting to note that aluminium has exactly the same temperature-coefficient of expansion as Bakelite and is therefore the ideal conductor with which to wind inductances whose formers are constructed from this latter material. Nor is this conductor entirely unsuitable for use in standard inductances for high radio-frequencies owing to the fact that, although the ratio of specific resistances of aluminium and copper is as high as 1.7, the ratio of their effective conductor resistances at high frequencies is only equal to the root of this figure (1.3), for wires of ample cross section, because "Skin-depth" is proportional to $\sqrt{\rho}$.

This form of construction, it will be seen, is very robust because of the strength of the Bakelite from which the end cheeks are

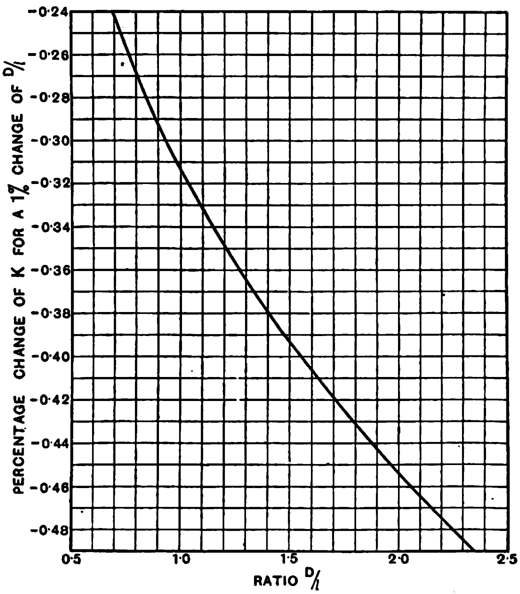


Fig. 3.

made, but the inter-turn field is kept well away from this material which has a high power factor. The power factor of the threaded cylindrical portion, being of ebonite or even of good loaded ebonite, is, on the other hand, very much lower than that of Bakelite, and so the turns of the winding may be allowed to rest in a screw thread groove without unduly increasing the dielectric losses of the completed inductance.

Moreover, the relative temperature-coefficients of linear expansion of ebonite (or loaded ebonite) and Bakelite are such that an almost complete compensation for thermal changes is obtained with this construction.

A good loaded ebonite to employ as a *B* material is that known as Keramot. This material although having relatively good electrical properties is much harder than pure ebonite and will withstand temperature changes much better. Although having a temperature-coefficient of expansion very nearly as high as ebonite, it has not the same tendency to distortion or "cold flow"

* Since this article was written the author has discovered a Bakelite having practically the same temperature-coefficient of linear expansion as that of copper, the actual figure being 20×10^{-6}.

when subjected to moderately high temperatures.

The electric strength of Keramot is 55 k.v. per millimetre, compared with 100 k.v. for best ebonite, and its power factor about one per cent., compared with 0.3 per cent. to 0.5 per cent. for ebonite. The per-

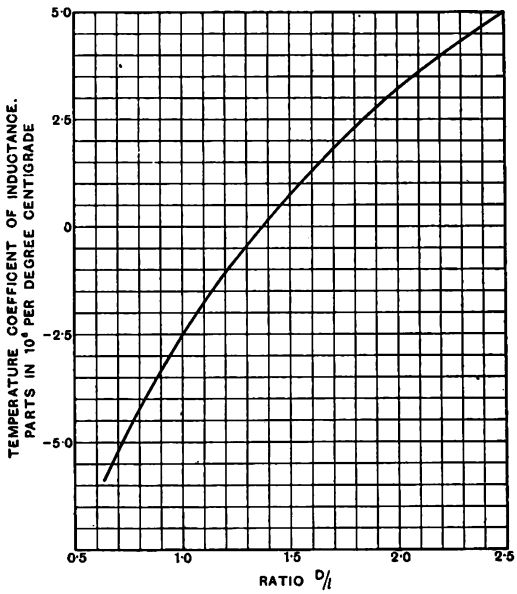


Fig. 4.
A. Material Bakelite.
B. Material ebonite or loaded ebonite.

mittivity of Keramot is not excessively high, being of the order 4.5.

The following comparison of best ebonite and Keramot is extracted from a tabulation of properties of ebonites supplied by the makers.

	Ebonite.	Keramot.
	Per cent.	Per cent.
Sulphur Content } Total ..	30.09	17.94
Sulphur Content } Free ..	2.94	0.47
Acetone Extract ..	4.95	2.40
Ash	0.75	28.08
Specific gravity ..	1.19	1.66

The Extent of Compensation.

In a single-layered helical coil of this type, changes of temperature will alter the two dimensions of the former, the diameter d and the axial winding length l and these, in turn, will affect three factors d^2, $1/l$ and K, of the formula for its inductance.

$$L = \pi^2 d^2 N^2 K/l.$$

For small temperature variations, therefore, the thermal changes of inductance value will be proportional to twice the linear expansion coefficient of the end cheek material, inversely proportional to the linear expansion coefficient of the axial framework material, and will also depend upon the factor K which will, of course, vary with the change of the ratio of d/l. The latter factor can, by suitably choosing the order of d/l, be made to augment the positive component of the thermal changes due to the A insulating material to such an extent that the resultant temperature-coefficient of inductance is almost negligible. Moreover, it is found that by employing two such materials as Bakelite and Keramot the order of the ratio d/l required for compensation is such as to satisfy also the conditions for an efficient inductance, *i.e.*, not small enough to reduce seriously its time constant and not large enough to increase seriously its self (distributed) capacity.

As an aid to the calculation of the resultant temperature-coefficient of inductance of a single-layered helical coil, the percentage change of the factor K for a given percentage change of the ratio d/l has been computed for all values of the latter ratio from 0.5 to 2.5: the results are plotted in the curve of Fig. 3.

By using this curve the resultant temperature-coefficient may rapidly be estimated with accuracy if the temperature-coefficients of linear expansion of the two insulating materials of the former are known.

If α = temperature-coefficient of linear expansion of A material and β = that of B material, then the temperature-coefficient of the ratio $d/l = \alpha - \beta$. The temperature-coefficient of K is therefore $\gamma\ (\alpha - \beta)$ where γ is read from Fig. 3 corresponding with the appropriate value of d/l.

The resultant temperature-coefficient of inductance

$$= 2\alpha + \gamma\ (\alpha - \beta) - \beta.$$

As an example, taking Bakelite for the A material, a good loaded ebonite for the B material, and a ratio of $d/l = 1.37$.

$\alpha = 25 \times 10^{-6}$ per degree centigrade.
$\beta = 65 \times 10^{-6}$,, ,, ,,
γ from curve $= -0.375$.

$\therefore$ Resultant temperature-coefficient of inductance

$$= 50 \times 10^{-6} - 0.375(-40 \times 10^{-6}) - 65 \times 10^{-6}$$
$$= 0.$$

It will be seen that the resultant temperature-coefficient of inductance can be positive or negative depending upon the shape of the coil in relation to the two insulating materials employed. For those materials for which the above example is given several values of overall temperature-coefficient of inductance have been computed and plotted against values of d/l. From the resulting curve (Fig. 4) it will be seen that coils widely differing in shape may be designed without appreciable temperature-coefficient: the ratio of d/l may vary between the limits of 0.7 and 2.5 without increasing the temperature-coefficient of inductance beyond $\pm 5 \times 10^{-6}$ per degree centigrade.

When considering this figure it is interesting to note that if the same material is used throughout for the construction of the coil former $\alpha = \beta$ and the temperature-coefficient of inductance becomes equal to that of linear expansion of the material used since d/l in this case remains constant. Thus

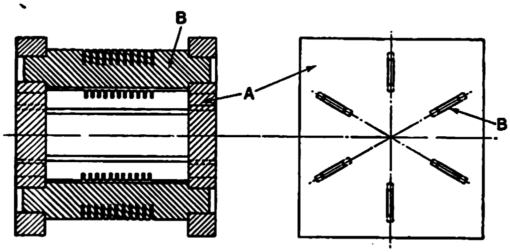


Fig. 5.

coils having formers constructed entirely from Bakelite and loaded ebonite, would have temperature-coefficients of inductance of the orders $+25 \times 10^{-6}$ and $+65 \times 10^{-6}$ per degree centigrade respectively.

The Compensation of Multi-layered Coil Formers.

Owing to the extreme difficulty of working materials whose temperature-coefficients are of a very low order, it becomes even more necessary to employ the method of compensation for the more elaborate formers such as are required for coils of the multi-layered type.

For coils in which the depth of the winding is small in comparison with its mean diameter and length, the principle of compensation

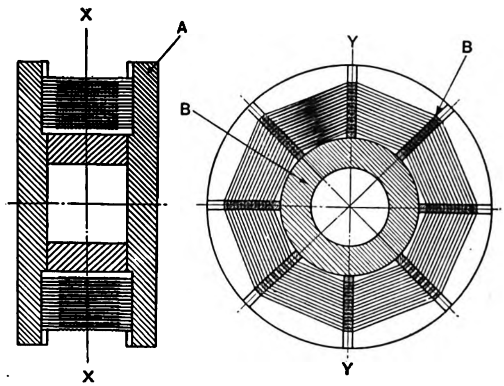


Fig. 6.

may be adhered to by employing the simple former construction indicated in Fig. 5. The A and B materials are in this case selected for compensation in exactly the same way as in the case of the single-layered helix; the same notation has been adopted.

For multi-layered coils of still greater inductance value, where the depth of winding is appreciable, the conductor is usually wound on a number of grooved distance pieces which are built up radially during winding to form spokes from a central hub. In this way each turn of the coil is air-spaced from all its neighbouring turns either of the same layer, or of adjacent layers. Such a coil is shown in Fig. 6.

This type of coil if constructed throughout from ebonite becomes very unstable when cycled through temperatures approaching those of tropical climates—with an increase of temperature the wire may cut more deeply into the grooves of the softened distance pieces, or the rapidly expanding former may stretch the conductor.

If this instability is more or less removed by constructing the former from loaded ebonite or even from Bakelite, an appreciable temperature-coefficient of inductance will still be present. If the former is constructed from the same material throughout it will have a temperature-coefficient equal

to temperature-coefficient of linear expansion of that material since in such coils:

$$L = \pi^2 d^2 N^2 K'/l \dagger$$

where K' is a factor which takes account not only of the ratio of the diameter to axial length, but also of the ratio of the axial length to the radial thickness of the winding. If all parts of the former are of the same material, these two ratios are, of course, unaltered by the expansion of its various

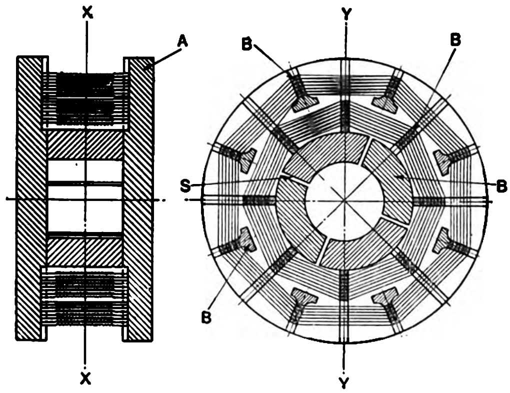


Fig. 7.

members due to a change of temperature, and K therefore remains constant for a given shape of coil.

By making a multi-layered air-spaced coil of this type from the two dissimilar insulators A and B as previously described, *instability* as well as excessive temperature coefficient can be eliminated provided that the winding is split up into two or more concentric sections as shown in Fig. 7 in order to reduce the extent to which the B material (from which the grooved distance pieces are made) affects the diametrical dimension of the winding. It will be seen from the drawing of Fig. 7 that the sets of grooved distance pieces of each section are built up radially independently of those of the other section or sections. In this manner the mean diameter of the outer section is not seriously affected by the thermal expansion of the distance pieces of the inner section, as would be the case were the coil to be built ordinarily in one section. The central hub of material B must, of course, be made discontinuous by the saw cuts S for the reason already given in the description of the single-layer helical inductance former.

† Dr. F. W. Grover, Scientific Papers, Bureau of Standards, No. 455.

Other Sources of Inconstancy—The Effect of Humidity.

When a standard inductance is used as a component of a simple resonant circuit for wavelength determination there is, in addition to the inconstancy due to changes of inductance value with age, lack of robustness and with variation of temperature, a distinct possibility of further calibration inconstancy due to changes of self (distributed) capacity with variation of humidity.

When the degree of constancy of frequency calibration of a simple parallel resonant circuit approaches the order one part in 10,000, changes of coil self-capacity cannot be immediately dismissed as negligible even when the coils are of good design and are associated with condensers of high capacity value. More especially, of course, is this the case with coils in which insulating materials having a high degree of moisture absorption are employed in positions such that appreciable electric field passes through them. For this reason alone therefore *silk* covered wires of adjacent turns of coils should not be allowed to touch, and cotton covering must, of course, be avoided entirely.

The design of the multi-layered coil shown in Fig. 5 would more particularly appear to offend in this respect since the turns in each slot are separated only by their covering of silk. This type of coil should therefore, it is thought, be avoided unless a more or less constant order of humidity can be ensured in the laboratory in which it is to be set up. Multi-layered coils should, for this reason also, be of the completely air-spaced type and the wire with which they are wound should have as little absorbent insulating covering as possible, depending rather upon the tautness of the winding to preserve a uniform air insulation between adjacent turns and layers. Thus, with the formers for such coils made more robust and permanent as shown in Fig. 7, it should be possible to employ Litzendraht wire which is merely enamel-insulated provided the winding is well done.

In order to ascertain the effect of humidity on the self-capacity of a typical efficient multi-layered coil the following experiment was performed. A sub-standard wavemeter

inductance of about 20 millihenrys was chosen for the experiment. It was a large coil designed to be of low decrement and completely air-spaced between turns and between layers and wound with double-silk-covered Litzendraht wire. Its former was somewhat similar to that shown in Fig. 6. It was set up (at a fixed loose coupling position) to absorb energy from the oscillatory circuit of a heterodyne wavemeter when the latter was tuned to its natural frequency. For this test, of course, the coil under trial was open-circuited—the natural wavelength being of the order 840 metres—and the resonance absorption tuning was shown by the slight indication of a milliammeter included in the anode circuit of the wavemeter. A comparatively crude measurement of natural wavelength in this manner could be made to show changes in self-capacity.

The coil was subjected to extremes of humidity alternately for periods of 48 hours, the whole test occupying several weeks and a quite definite maximum natural wavelength change of 3 metres was obtained—this representing a 0.7 per cent. change in effective self-capacity which would effect a maximum wavelength change considerably less than one part in 10,000 in a resonant circuit whose capacity was not reduced below 500 $\mu\mu$F. It would appear therefore that this type of coil is just good enough, from this point of view, for use in the very best sub-standard wavemeter circuit even under these extreme conditions of atmosphere.

Conclusion.

In conclusion it should, perhaps, be mentioned that the natural frequency of a simple parallel resonant circuit is dependent to some extent upon its resistance. Changes of dielectric loss in a sub-standard wavemeter inductance will therefore tend to produce changes of frequency calibration, and such changes must inevitably occur with variation of humidity. In almost any design of coil however, such changes are of a negligible order, while in well-designed efficient inductances such changes of natural frequency would never, it is thought, exceed a few parts in a million under laboratory conditions, even if the dielectric component of the loss was predominant in the design.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Frequency Modulation.

To the Editor, E.W. & W.E.

SIR,—In my letter on the above subject, published in the August issue of *E.W. & W.E.*, I made the statement that since the carrier current is going through the frequency value ω_3 (comprised between ω_1 and ω_2) twice during every cycle of the modulating vibration, it comprises a component current of frequency ω_3 flowing in the circuit $2m$ times per second and for but a few cycles every time, and having hence an amplitude which is modulated at the *fundamental* frequency $2m$ between zero and the constant maximum amplitude of the actual carrier current.

This strictly is true only for the high-frequency current component of frequency

$$(\omega_1 + \omega_2)/2$$

which is assumed by the high-frequency current at *regular* time intervals, equal to $1/2m$ seconds.

Any other frequency value comprised between ω_1 and ω_2 will also recur $2m$ times per second, but at time intervals which are alternately greater and smaller than $1/2m$, the sum of two such successive time intervals remaining, however, equal to $1/m$. This introduces a component of frequency m in the amplitude modulating force of the high-frequency current component considered, but does not invalidate the conclusions of my previous letter. The reason is that this amplitude modulating force component of frequency m expresses the recurrence asymmetry of any frequency value of the high-frequency current (except of the value $(\omega_1 + \omega_2)/2$ for which the asymmetry disappears), while the modulating force component of frequency $2m$ represents the recurrence frequency of the particular carrier current frequency value considered.

Even a rough analysis of the frequency modulated current must at least take these two terms into consideration, and as shown in my previous letter, this leads to the conclusion that the frequency band width of the frequency modulated current is equal to $k + 4m$.

This, of course, does not take into account the fact that each frequency value between ω_1 and ω_2 is assumed by the high-frequency current for a very short time only. If this be considered, higher harmonics of m will enter into line, and the value found for the frequency band width will be correspondingly larger. But since the object of my last letter was to estimate a minimum value of this frequency band width, that is, the least value which it has if only the most essential factors are considered, the conclusions remain correct.

Paris. H. LAUER.

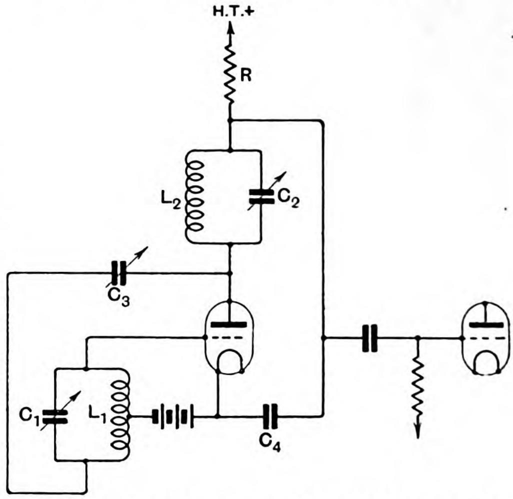
Reduction of Distortion in Anode Rectification.

To the Editor, E.W. & W.E.

SIR,—The whole point of Mr. A. G. Warren's article under the above title in the August *E.W. & W.E.*, seems to depend on the "straightening effect" of the anode resistance on the static characteristic of the valve. That such an effect exists has been somewhat vaguely realised by experimenters for many years, it was the basis of an article by Dr. Kröncke in *The Wireless World* on September 23rd, 1925, and was mathematically demonstrated by Colebrook in *E.W. & W.E.* for April, 1927. The improvement can be seen by taking the anode current/grid voltage curve by the ordinary static method, and it can be taken advantage of in *low frequency* amplification. Unfortunately, however, the effect is not operative in the case of an anode bend rectifier with a plain anode resistance, for it is necessary that the impedance in the anode circuit should be large compared with that of the valve *for the frequency under consideration*, and as the rectifying valve may be regarded simply as an "asymmetrical H.F. amplifier," the presence of the by-pass condenser vitiates the whole argument, for it is the carrier frequency which must be considered.

Under the actual conditions of operation it is the ordinary static curve which must be taken, and among the large number of valves I have tested I have found none which deviates materially from the simple parabola within the limits of the useful part of the curve, which fact leads back to the conclusion that the distortion is a function of the percentage modulation only, and cannot be reduced by increasing the input. On the question of modulation depth, I fear that Mr. Warren is unduly optimistic in stating the maximum as 20 per cent. Peak values of something around 80 per cent. regularly occur. The B.B.C. have stated that the tendency will be for modulation percentage to increase, and that 5GB at present has provision for 100 per cent. It is probably true that the *average* modulation is around 20 per cent., but we certainly must provide for the peaks if we are aiming at anything like perfection. For some time past I have been conducting experiments on a system which includes a tuned circuit in series with the rectifier anode, as in the accompanying sketch. L_2C_2 is the circuit referred to, R is the anode resistance (whose value is fixed by considerations of amplification only) across which the L.F. voltages are developed. C_1L_1 is the usual grid circuit, and the by-pass condenser C_4 may be included if desired, although its function is not obvious in such an arrangement. The system must be neutralised by means of the condenser C_3. It is perhaps a disadvantage that the system introduces an extra tuning control, but as the tuning does not seem to be of great importance, and as, moreover, with the values mentioned below, the tuning is very flat (the circuit being shunted by a very low resistance valve) the process is very easy, and further, these facts immediately suggest "ganging" as a complete solution.

With individual control, the method is as follows: Having first tuned the preceding H.F. circuits, including C_1L_1, upset the neutralising condenser C_3 by a small amount sufficient to produce oscillation on swinging C_2, set C_2 to the middle of the oscillating range and then return C_3 to its correct position. This completes the adjustment, and the process is not nearly so complex as it sounds.



Using a P625A valve (R = 1,650ω) in conjunction with a tuned circuit of high efficiency giving an impedance of about 250,000ω at resonance, then when the unmodulated input has a peak voltage of 7, a modulation depth of 80 per cent. can be dealt with while the sensitivity for the troughs of the modulation remains 80 per cent. of that for the peaks, while with a modulation of 40 per cent. the ratio rises to 95 per cent. Better figures can be obtained with increased inputs. These figures are arrived at by calculation, of course, but it is demonstrable by shorting the tuned circuit that they are to a large extent realised in practice. While it is difficult to detect anything by setting C_2 off tune (owing partly to the flatness of tuning) there is an unmistakable difference on shorting the tuned circuit out, particularly on speech.

Stratford-on-Avon. P. G. DAVIDSON.

P.D. and E.M.F.

To the Editor, E.W. & W.E.

SIR,—1. Definitions of quantities are purely matters of convenience, and two separate sets of definitions may be independently correct; they will be so long as they are self-consistent.

2. Any set of definitions must not only be mathematically rigorous, but also submit to the generally accepted conventions of the use of the terms defined.

These two statements were given at the beginning of my article on fundamental definitions, which has been subjected to considerable critical examination by Mr. Biederman. These two statements are, I believe, rigorously true, but their function is far from perfect, for they allow considerable variations depending on personal opinions.

According to the first statement, the best definition is that which is most convenient. It is unnecessary to emphasise how personal opinions may differ in using convenience as a criterion of the quality of a definition. In the second statement the bone of contention will be found in the phrase " . . . must submit to the generally accepted use of the terms defined." There exists, therefore, two important conditions of the suitability of a definition, which are essentially dependent on personal opinions. In this article I would like to make it perfectly clear that the difference between Mr. Biederman and myself is a difference of opinion, and is not due, as Mr. Biederman thinks, to an omission on my part of an important element of the problem.

The whole argument centres round the equation

$$\mu \frac{\delta A}{\delta t} + \frac{\delta \phi}{\delta s} + Ri = 0 \quad \ldots \quad \ldots \quad (1)$$

where A is the vector potential and ϕ is the scalar potential.

The problem of satisfactorily defining potential difference and E.M.F. resolves itself in finding the best method of dividing the first two terms of the above equation into two parts, one of which will give the potential difference and the other the E.M.F.

I divided these two terms in the simplest possible way from a mathematical point of view. I divided the terms so that one part was produced by the distribution of charge alone and the other by the distribution of current. The charges alone are responsible for the $\frac{\delta \phi}{\delta s}$ term, from which the potential difference could be calculated by simple addition, while the currents produce the $\frac{\delta A}{\delta t}$ term, which gives the E.M.F. It is evident that the fact that the potentials are in reality retarded potentials does not affect the validity of such a definition. That is the reason why I did not emphasise the fact and simply inserted it as a footnote so as not to distract the attention from the main issue. The wording of that footnote may well have been unfortunate, since it forms the main basis of the destructive part of the criticism of Mr. Biederman. I said that at high frequencies it was sometimes necessary to take into account the fact that the potentials were retarded potentials. Rigorously, this fact must always be taken into account, but in practice this need only be done at high frequencies.

Though I disagree with the nature of Mr. Biederman's destructive criticism, my attitude to his constructive criticism is the exact opposite. I will not try to judge whether Mr. Biederman's definition or mine is more suitable, for that is the duty of the users of the definitions and not of the proposers, who should only point out the advantages and disadvantages of the various definitions available.

Mr. Biederman ingeniously points out that the $\frac{\delta \phi}{\delta s}$ term of equation (1) can be split up into two parts, one of which reduces to zero, when the electrical conditions do not vary with time. This part he adds to the $\mu \frac{\delta A}{\delta t}$ term to produce the E.M.F., while the rest is the potential difference. His main argument for this is that forces of an electromagnetic nature are never associated with potential difference. That is, all the electric forces produced by electrical variations with regard to time are generally considered to produce E.M.F.s only. I would not like to state whether this is true or not, for it is largely a matter of opinion, yet it is of some importance, for it is the chief reason Mr. Biederman has for considering my definition as impossible. I may state this, however: Before writing my original article on the subject, I endeavoured to obtain an idea of what were the generally considered views on the meaning and use of the terms Potential Difference and E.M.F. I asked a number of physicists, mathematicians and engineers, and was very much astonished by the very great variety of views held. I think Professor Howe can confirm this statement from his own experience. The only general agreement I could find was that the potential difference was equal to the ohmic drop plus the E.M.F., and that Faraday's law played an important part in the definition of E.M.F. This allows considerable latitude in our definition, the remaining criterion, according to our first axiom, is convenience.

Before continuing, I would like to emphasise that these statements must not be taken as dogmas, but merely as my personal opinion and experience.

When dealing with mutual inductance, either between two circuits or two portions of the same circuit, the forces induced from one to the other can be split up to produce electric and magnetic couplings. In my definition I joined them into a single term, the total being an E.M.F., for I thought that this would be more convenient, although it departs from the usual conventions, but there is no reason why the electric and magnetic components should not be separated, if this is considered to be desirable. If my definition of E.M.F. be so divided into a potential difference for the electric coupling and an E.M.F. for the magnetic coupling, the nature of the coupling between two distant antennæ will be a combination of electric and magnetic couplings. The advantage of Mr. Biederman's definition is that, although the coupling in this case will also be a combination of electric and magnetic, the electric coupling will be negligibly small.

I think I have said enough to explain in what way the definition due to Mr. Biederman and mine differ. My reply to the various other points of criticism brought out by Mr. Biederman can be imagined by the reader, and I do not think it is necessary for me to enter more explicitly into the

details of the question in order to explain my point of view. There is one point, however, that I wish to consider. That is the argument at the end of Mr. Biederman's article. The definitions as he correctly states must be correct for all conditions including, therefore, the case of a direct current circuit. Mr. Biederman starts by pointing out that my definitions are physically incorrect in this case and then explains how they still remain consistent; hardly logical, yet it sounded conclusive. The argument turns, however, on the same criterion—What is the generally accepted meaning of the terms used? If we consider two parts of the same circuit and try to evaluate the potential difference between two extreme points A and C on the part ABC, is it not natural to consider the potential difference between A and C due to the electrical conditions on the part ABC alone and add to it that due to the electrical conditions on the remainder of the circuit, calling the latter an E.M.F.? This E.M.F., however, will become a potential difference, if, as suggested above, my definition of E.M.F. be divided into a potential difference due to electric coupling and an E.M.F. due to magnetic coupling. That is what my definition necessitates. It may be that Mr. Biederman and probably many others will not consider this procedure to be natural, but it may also be that many others will hold a different opinion.

I would like to emphasise one point in which the opinion generally held does not seem to me to be scientifically correct. That is the enormous difference which is supposed to exist in the mutual relation between parts of the same circuit and between two circuits coupled together. If a circuit contains two large condensers, although there is no metallic connection between the two parts of that circuit, the relation between these two parts is usually considered to be of a totally different nature to those that exist between two circuits that are at a greater distance apart. It appears to me that the difference is one of degree and not one of nature. That is the reason why I consider that definitions of potential difference and E.M.F. should be applicable to portions of circuits as well as to apparently separate circuits.

In concluding this reply to Mr. Biederman, I do not wish to be misunderstood. I consider Mr. Biederman's suggestion of the greatest interest and of considerable importance, but that is no reason why he should not consider the possibilities of other opinions. My definition possesses the advantage of considerable mathematical convenience, an important matter, since physical quantities in the present state of development of the art are not of great value unless they can be conveniently evaluated. The advantages of Mr. Biederman's definitions lie in the simplification of the type of coupling existing in certain cases. As I said previously, I do not think that it is for either of us to decide which definition agrees best with conventional ideas on the subject, or which is likely to be the most convenient to the majority of users.

R. M. Wilmotte.

Radio Frequency Laboratories, Inc., Boonton, New Jersey, U.S.A.

On the Writing of Scientific Papers.

To the Editor, E.W. & W.E.

Sir,—I read with considerable interest Mr. Colebrook's article under the above heading in the issue of *E.W. & W.E.* for June, 1929. Mr. Colebrook has given an able exposition of the important elements in the application of the scientific method and the writing of scientific papers. Often the responsibility of editing one's own paper devolves upon the scientific worker, and it is a long way from the manuscript to the final printed stage of a paper. In this connection may I draw the attention of the readers of your journal to a contribution from the distinguished pen of Dr. M. O. Forster, F.R.S., entitled "Preparing Papers for the Press" in "Electrotechnics No. 2," published in the Indian Institute of Science, Bangalore, India.

Piloting one's own paper from the manuscript to the print is a chastening experience. A close attention to detail is absolutely essential and this comes only with practice. It is astonishing to see the number of tiny errors which crop up in an apparently well-written manuscript, under the blue pencil of an experienced editor. Errors such as want of uniformity in giving references to the literature, unconscious change from capitals to the lower case and from Roman to Arabic numerals, inconsistencies like kilograms appearing in different places as kilos., kgm., kgs., and kg., etc., easily escape the eye of many. In a scientific paper italics must not find a place except for special reasons. Equally with italics, clichés must be avoided. A great pitfall is the person in which the paper is written, which, unless carefully watched, has a tendency to oscillate between first and third. One can easily imagine the impropriety of a modest beginning such as "the writer" or "the author" blossoming finally into "us" and "we."

Mr. Colebrook has chosen a happy example in the clay worker to illustrate how a scientific paper must take shape. The ideal to be aimed at is conciseness and freedom from ambiguity. It is a good plan to forget a paper once it is written and then come back to it with a fresh mind after an interval of time. Not only possibilities of clearer presentation but crucial experiments are likely to suggest themselves.

T. S. Rangachari.

Electrical Communication Laboratories, Indian Institute of Science, Bangalore, 27th June, 1929.

The Definition of Selectivity.

To the Editor, E.W. & W.E.

Sir,—In his very interesting article on "The Definition of Selectivity," Mr. Colebrook has put forward as a basis for discussion the proposal that, when the amplitudes of two simple harmonic alternating electrical quantities in any network of conductors are related by an equation of the form $B = A/Z$, the selectivity of the circuit with respect to the quantity B shall be defined as the quantity $\omega \sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial \omega_r^2}\right|}$. The radical sign has no doubt been introduced because actually the relation

between B and A is usually of the form $B = A/\sqrt{Z^2}$.

For a frequency differing by $\frac{\delta\omega}{2\pi}$ from that frequency $\frac{\omega_r}{2\pi}$ for which $\frac{\partial Z}{\partial\omega} = 0$, the value of B for the same value of A is given by

$$B' = A/\sqrt{Z_r^2 + \tfrac{1}{2}\frac{\partial^2(Z^2)}{\partial\omega_r^2}\delta\omega^2 + \text{etc.}}$$

so that

$$\frac{B}{B'} = \sqrt{1 + \frac{\omega_r^2}{Z_r}\frac{\partial^2 Z}{\partial\omega_r^2}\left(\frac{\delta\omega}{\omega_r}\right)^2 + \text{etc.}}$$

In many instances, no doubt, the series under the radical sign is a rapidly converging one, so that, *for a given value of* $\frac{\delta\omega}{\omega_r}$, the selectivity is practically dependent only on the coefficient of $\left(\frac{\delta\omega}{\omega_r}\right)^2$, and it is the square root of this coefficient which Mr. Colebrook proposes as the definition of the selectivity of the circuit.

There are, however, cases of commom occurrence where the series is not so rapidly convergent—where, in fact, terms involving higher powers of $\frac{\delta\omega}{\omega_r}$ may have values comparable with that involving $\left(\frac{\delta\omega}{\omega_r}\right)^2$ for such values of $\frac{\delta\omega}{\omega_r}$ as occur in practice. A case in point is that of two loosely coupled tuned circuits. It therefore seems a little arbitrary to define selectivity solely in terms of the coefficient of $\left(\frac{\delta\omega}{\omega_r}\right)^2$.

Again, even if we limit consideration to those cases where the terms involving higher powers of $\frac{\delta\omega}{\omega_r}$ than the second are negligible, is it not the coefficient of $\delta\omega^2$ rather than that of $\left(\frac{\delta\omega}{\omega_r}\right)^2$ which is the significant quantity in determining selectivity? For in practice we are concerned with the relation between signal strength at the resonant frequency and that at a frequency *differing by some specified amount from the resonant frequency*. We are not primarily concerned with the *ratio* of this frequency difference to the resonant frequency at all.

Take, for example, the case of current resonance in a simple series circuit as dealt with by Mr. Colebrook in the appendix. We have

$$\frac{I}{I'} = \sqrt{1 + \frac{4L}{CR^2}\left(\frac{\delta\omega}{\omega_r}\right)^2}$$

With Mr. Colebrook's definition the selectivity is equal to $2\sqrt{\frac{L}{CR^2}}$, which decreases with increasing capacity for given values of L and R. But since the resonant frequency is given by $\omega_r^2 = 1/LC$, we have

$$\frac{I}{I'} = \sqrt{1 + 4\frac{L^2}{R^2}\delta\omega^2}$$

which, for given values of L, R and $\delta\omega$, is independent of the capacity, and it is essentially by the ratio $\frac{I}{I'}$ at some frequency difference that we judge of the degree of selectivity of the circuit.

Again, with Mr. Colebrook's proposed definition, the selectivity of a tuned anode circuit is greater the smaller the capacity (for a given frequency), whereas it is generally recognised that the reverse is the case.

If, therefore, we are to define selectivity in terms of one coefficient, it should be in terms of the coefficient of $\delta\omega^2$ rather than that of $\left(\frac{\delta\omega}{\omega_r}\right)^2$.

Since, however, as Mr. Colebrook admits, we cannot cover all cases by defining selectivity in terms of any one coefficient (in the series for Z^2), I suggest it would be preferable to define it as *the ratio of the quantity concerned at the resonant frequency to that which it has at a frequency differing by some specified amount from the resonant frequency.* We might speak of the selectivity thus defined as having such and such values at frequency differences of 10, 15 or 20 kilocycles or some one standard frequency difference might be employed in the definition so that one definite numerical value could be assigned as specifying the selectivity of a circuit.

Incidentally, the inverse of the selectivity, so defined, for a frequency difference of 10 kilocycles is a measure of the extent of the cutting-off of the sidebands and might be termed the "quality factor" of the circuit.

E. A. BIEDERMANN.

Brighton.
August 7th, 1929.

L.F. Transformer Curves.

To the Editor, E.W. & W.E.

SIR,—The article in a recent issue on the Philips Transformer and the widespread publication of frequency response curves, certified and otherwise, raises a question as to whether these curves are taken under conditions which represent accurately the working conditions. All the curves which I have seen show the frequency response curves taken with a pure resistance load in the anode of the valve on the secondary side of the transformer. As this load under actual conditions is nearly always a reactive load (either predominantly inductive or capacitive, according to frequency), which is not of a reasonably constant value, it would appear that the input impedance of this output valve is not nearly the constant quantity obtained when a pure resistance load is used. The varying input impedance must therefore affect the transformer characteristic, particularly when the valve capacities are used to promote resonance and keep up the amplification of the higher audio-frequencies. Would it not be very interesting to have the characteristics taken with an actual loud speaker load in the anode circuit. We would then be able to obtain the curves under actual working conditions. I should, of course, be happy to be assured that the characteristics published are in close agreement with those obtained under actual working conditions.

W. SYMES.

Hence

$$\delta f = \frac{\delta C}{2C} \cdot f_0$$

$\therefore$ $\delta f/\delta C = f_0/2C =$ *constant,* if we assume that the variation of C over this range is very small.

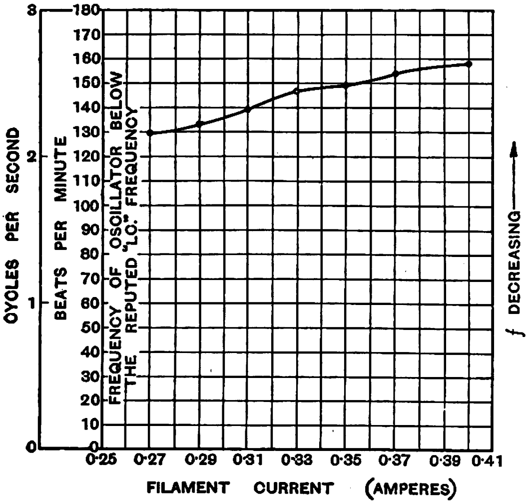


Fig. 6.—*Deduced curve from curves in Fig.* 5. *Frequency variation with filament current. Va,* 63 *volts ; G.B.,* 1.5 *volts ; coupling,* 21 *cms. ;* 67.4° *F., room ;* 64.8° *F., fork.*

Hence by extrapolating the curves as straight lines we get an approximate value of frequency departure when $C = 116.51$ jars for each particular filament current.

These values are plotted in a curve in Fig. 6 and are seen to agree to some extent with the curve A in Fig. 11 ; the conditions of temperature and grid bias for the two curves are different. In this previous test the following were the conditions :—

Anode voltage = 63 volts.
Anode current = 1.6 mA.s (1.8 volts on filament).
Grid bias = 1.5 volts.
Grid coupling = 21 cms. (*i.e.*, M = 142 mH.s).
Fork temperature = 64.8 deg. F.
Room temperature = 67.4 deg. F.

From this curve we find that the frequency f of the oscillator is below the "LC" frequency f_0 by an amount varying from 129 to 158 beats per minute according to the filament current, *i.e.*, about $2\frac{1}{2}$ cycles per second below the "LC" frequency. We will discuss this result in the light of the theory just evolved in a later sub-section.

(d) *Expected Accuracy of Results.*

The beats in the telephones can be heard distinctly and counted accurately up to about 189 beats per minute. This was found difficult at first, but by counting in tens and making a mark on paper for each ten the counting became automatic and fairly accurate. In the resistance adding test the frequency departure was as high as 256 beats per minute for some of the measurements. This required extreme concentration and was accomplished by counting consecutive fours up to ten so that pencil marks were made at each forty and counted afterwards. The third figure had to be guessed at in this case.

The experimental frequency departure from the reputed "LC" value was never much smaller than 120 beats per minute (*i.e.*, 2 cycles per second), and the actual variation of frequency over one curve was never greater than 45 beats per minute (or 0.75 cycles per sec.) except in the case of resistance variation in the oscillatory circuit, when the frequency variation was as much as 110 beats per minute (or 1.8 cycles per second). For each curve the temperature

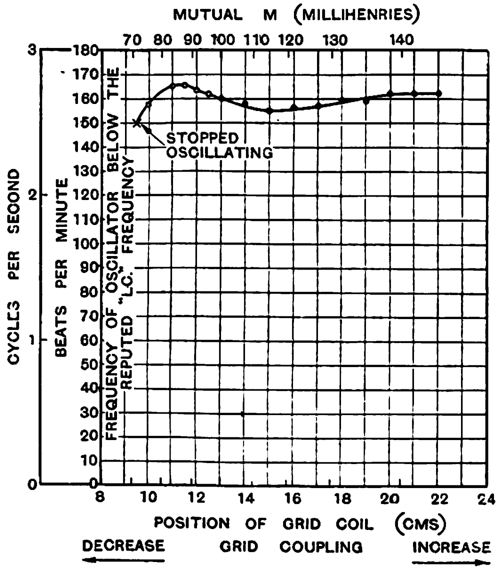


Fig. 7.—*Frequency variation with grid coupling. H.T.,* 60 *volts ; L.T.,* 2 *volts ; G.B.,* 1.5 *volts ;* 65° *F., room ;* 63.2° *F., fork.*

variation in the constant temperature cell was very small, as the whole curve was taken in about 20 minutes and so the error between consecutive readings on one curve may be considered negligible. Curves as a whole, however, and the frequency determination of the fork were taken on different days and the maximum temperature range in the cell over some weeks must now be considered, *i.e.*, about 6 deg. F. or 3.33 deg. C. Hence maximum frequency variation of fork in this time (taking Dye's figure) is 3.33×1.15 parts in 10,000, *i.e.*, 3.83 parts in 10,000, or 0.049 cycles in 128, *i.e.*, 0.245 cycles in 640 cycles.

Our minimum frequency departure obtained by experiment is 120 beats per minute (or 2 cycles per second), so that our possible error in frequency departure measurement due to temperature changes alone may amount to as much as 0.245 cycles in 2 cycles, *i.e.*, 12.25 per cent., which is quite considerable. The necessity for a really constant temperature cell in future investigations is again stressed in the light of these figures. We must remember at the same time that we assume our f_0 exactly correct (this depends on measurements of L and C). The frequency departure as we have just determined it is $2\frac{1}{2}$ cycles below the f_0 frequency. That is, we have measured $2\frac{1}{2}$ cycles in 640 or 0.39 per cent. So far we have assumed that L and C are set so that the reputed "LC" frequency will correspond exactly with 638.706 . . . cycles; but can we measure L and C sufficiently closely to guarantee accuracy to within even 0.39 per cent., let alone exactness ?

$$\text{Now} \quad f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\text{and } f_0 + \delta f_0 = \frac{1}{2\pi\sqrt{(L+\delta L)(C+\delta C)}}$$

$$= \frac{1}{2\pi\sqrt{LC}\sqrt{1+\frac{\delta L}{L}+\frac{\delta C}{C}}}$$

$$= f_0\,\{1 - \tfrac{1}{2}\,(\delta L/L + \delta C/C)\}$$

$$\therefore \quad \delta f_0 = -\tfrac{1}{2}\left(\frac{\delta L}{L} + \frac{\delta C}{C}\right).$$

So if we have the true C and L values both greater than the measured values by 0.39 per cent. the real f_0 will be 0.39 per cent. lower than it was thought and our measured frequency departure would be about zero. It is possible that even greater error exists in the L and C measurement so that although we find experimentally that the oscillator frequency is below the "LC" frequency, it may quite conceivably be above. If we are to be able to determine experimentally the exact frequency departure positive or negative we must have extremely accurate values of L and C, say 1 or 2 parts in 10,000. This would necessitate very refined work and would require a constancy of conditions, measurements all being made *in situ* and at the same temperature and frequency. The need for such extreme refinement was not realised at the time of measuring L and C, and so although very great care was taken in getting accurate values the foregoing precautions were not taken. The frequency at which the measurements were made was about 700 or 800, the temperature was not the same, and the measurements were not made with the whole apparatus assembled in position. The condensers were measured assembled together with the leads, and it had been thought that this would be sufficiently accurate. The method used was the Carey Foster Bridge and great care was taken to use suitable values of resistances as recommended in Hague's "A.C. Bridge Measurements." Readings were taken with the condensers in parallel adjusted to give a capacity near about the required C value. Any necessary adjustments could then be made on one of them (a finely variable 2-jar condenser, calibrated by comparison with a standard air condenser) to give as accurate a value as possible for the fixed C. The values were probably accurate to about 5 parts in 10,000. L was measured using a 100,000 μH. mutual inductometer with a 10-to-1 step-up ratio. The mean of several readings was accepted and could be relied upon to about one part in 1,000 only, in spite of a well-tuned galvanometer and careful readings. Self-capacity of the inductance coil should not be large at this frequency especially as the windings are sectionalised.

Let S be the self capacity.

L_m the measured value of L.
C_m the measured value of C.

The effect of S is to make $L_m >$ true L, and $C_m <$ true C.

Hence the tendency to obtain a false "LC" value due to self-capacity should not be very great.

The foregoing remarks are fully stressed at this period so that when work is continued on this subject sufficient accuracy is made to determine with confidence the exact frequency departure above or below the "LC" frequency.

In Fig. 10 are shown 2 curves which were taken on different days, but with the same conditions, but for the fact that the temperature differed by 2 deg. F. If we adopt Dye's experimental value we would assume that the tuning fork frequency had decreased slightly by 0.082 cycles per sec., as the temperature had increased (since we have previously estimated a change of 0.245 cycles for 6 deg. F.). On day A the fork temperature was 67.0 deg. F., and on day B, 69.0 deg. F., and on day B, f_0 had decreased by $0.082 \times 60 = 4.9$ beats per minute. Now in all the curves obtained, the oscillator frequency is below the reputed "LC" frequency, f_0. So if f_0 decreases slightly by 4.9 beats per minute on day B, we should expect curve B to be identical with curve A in shape, but nearer to the "LC" frequency by 4.9 beats per minute. In practice, the curves were not quite identical, probably owing to instability at the low coupling values, but at the stable end towards the right we see that the practical results do agree with our theoretical expectations, for the curve B is nearer to f_0 than curve A by about 5 beats per minute. This result lends some support to the use of Dye's figure in the case of low-frequency forks. In the absence of further information on low-frequency forks, we accept this figure as being applicable to the present 128 cycle fork in use, viz., 1.15 parts increase in 10,000 for 1 deg. C. decrease in temperature.

(e) *Approximate Theoretical Values.*

It will be helpful here to estimate roughly the numerical values of the various terms of the equation 7, given in the theory in sub-section (*b*).

Now $C = 0.128 \times 10^{-6}$ farads.

$L = 0.484$ henry.

$L_1 = 0.14$ henry.

$M = -0.073$ to -0.14 henry.

$$\left.\begin{aligned} \mu &= 7.4 \\ R_a &= 18{,}530 \text{ ohms.} \end{aligned}\right\} \text{Particular values from Static Characteristic.}$$

$R_g = 10^4$ to 10^5 ohms (say).

$R = 19$ ohms.

Half of these figures are variable according to the conditions prevailing, so it is difficult to get any accurate calculations on the matter, but our purpose at present is to see the relative importance of the terms.

We will take M at the 0.14 value (corresponding to 21 cms.) and R_a at 20,000 ohms, though it is probable that this value increases considerably when oscillations are

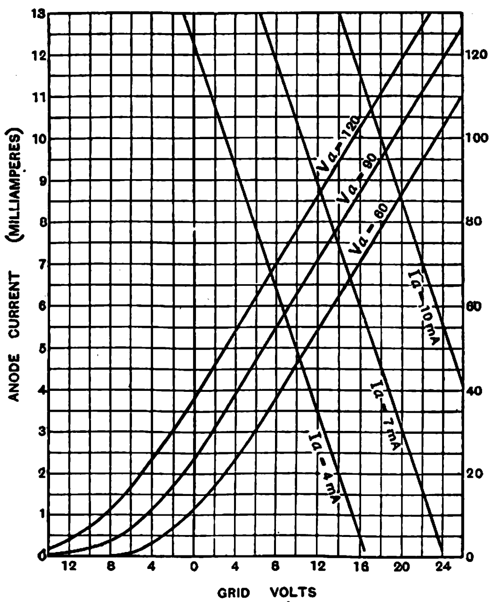


Fig. 8.—*Characteristics of Marconi D.E.R. (The Thermionic Oscillator.)*
$\mu = 7.4$, $Ra = 18{,}530$ *ohms.*

set up and the amplitude increases. Take R_g at 10^4 ohms, say. Then :—

$$\frac{R}{R_a} \approx 0.001.$$

$$\frac{M^2}{LCR_aR_g} \approx 0.0016.$$

$$-\frac{\mu}{R_a} \cdot \frac{ML_1}{R_g} \cdot \frac{1}{LC} \approx 0.0114.$$

It is thus obvious that the bottom right-hand term of the ω^2 equation is the important factor in the frequency variation.

We must bear in mind continually, however, that conditions are never constant, both R_a and R_g probably varying to a great extent as oscillations are set up. However, the aforementioned term will still be the important term, and we should look there mainly for an explanation of the various frequency changes. Frequency roughly estimated from above figures give:

$$f = f_0\sqrt{\frac{1 + .001}{1 - .0016 + .0114}}$$
$$= f_0\sqrt{1 - .0088}$$
$$\underline{f = f_0\,(1 - .0044)}$$

That is, if we were to rely upon the above approximations we should expect a frequency departure, under certain conditions, of:—

$$\underline{0.0044\,.\,f_0 \text{ below } f_0}$$

i.e., about 0.0044×640
$= \underline{2.8 \sim}$ or $\underline{170 \text{ beats per min.}}$ below f_0.

In actual practice assuming the "LC" measurement to be sufficiently accurate, the frequency departure varied from about 120 to 160 beats per minute below the f_0.

If we deduce the critical M from equation 2.

$$M = -\frac{1}{\mu}\,(CRR_a + L) \quad \text{for no grid current.}$$
$$= -\frac{1}{7.4}\,(.0452 + .4845)$$
$$M = -\underline{0.073 \text{ henry}}.$$

This agrees rather well with the experimental value, as we might expect seeing that conditions before oscillation are quite steady and therefore the above values apply. In Fig. 7 it may be seen that oscillations commence at 9.5 cms. grid coupling, or 71.5 mH.'s.

Assuming grid current the equation is as in 8.

$$M = -\frac{1}{\mu}\left(CRR_a + L + \frac{M^2R_a}{LR_g}\right)$$

$\frac{M^2R_a}{LR_g}$ is approximately 0.012 taking $R_g = 10^4$ and M about 0.073. Then $M = 0.0745$ henry.

(f) *Grid Coupling and Grid Bias.*

The first conventional test in which the frequency departure was measured direct, the capacity being constant at C, was made while determining the effects of variable grid coupling. In this case the H.T. voltage was still only 60.

Conditions were:

$$V_a = 60 \text{ volts.}$$
$$V_f = 2 \text{ volts.}$$
$$I_a = 1.68 \text{ mA.'s.}$$
$$I_f = 0.4 \text{ amp.}$$

The curve is shown in Fig. 7. It is rather curious in virtue of the increase in the number of beats as the mutual increases, then the crevasse, and finally a rise in the curve to a more or less steady value. The oscillator ceased to oscillate when the grid coil was withdrawn as far as 9.5 cms. The corresponding mutual at 9.5 cms. is 71.5 mH.'s. A true explanation of the shape of the curve is not possible owing to the variability of the μ, R_a and R_g terms in the frequency equation:

$$f^2 = f_0^2\,\frac{1 + R/R_a}{\left\{1 - \frac{M^2}{LCR_aR_g} + \frac{\mu}{R_a}\cdot\frac{(-M)L_1}{R_g}\cdot\frac{1}{LC}\right\}}$$

We can, however, assume certain changes and see whether the results based on these hypothetical occurrences agree with actual fact.

The chief point to bear in mind is that as the value of M increases, the amplitude of oscillation increases and R_a will increase, R_g will decrease, and $\frac{\mu}{R_a}$ or G will decrease. When oscillating strongly, grid current will be increased, indicating that R_g is small, but when only just oscillating, R_g is probably large. Hence we may say generally that the importance of the $\frac{\mu}{R_a}\cdot\frac{ML_1}{R_g}\cdot\frac{1}{LC}$ term is considerably lessened when oscillations are weakened or when large grid bias is employed, but becomes quite important when oscillations are strengthened.

In the curve on Fig. 7 there is a sudden rise at the beginning when oscillations are just commencing, indicating a decrease in frequency. This is probably due to the increase in R_a which lessens the R/R_a term in the numerator. Now R_g decreases and so the effect of the $\frac{\mu}{R_a}\cdot\frac{ML_1}{R_g}\cdot\frac{1}{LC}$ term becomes felt. M is negative, so an increase in R_a will

cause an increase in f due to this term, and this term is becoming continually more important until R_g settles down to a steady value. Oscillations now being strong, there is probably little further change in R_a, and the

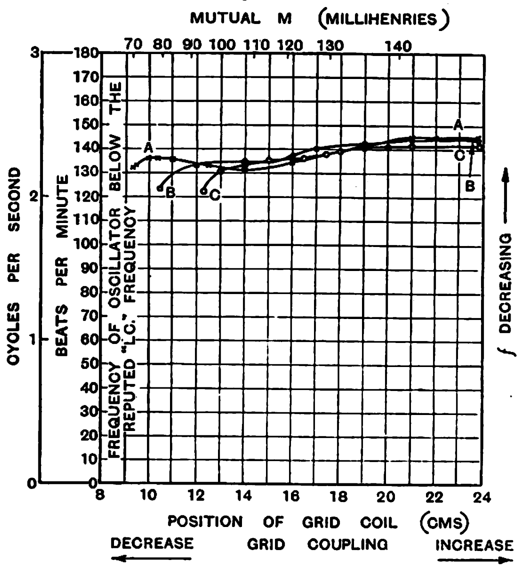


Fig. 9.—*Frequency variation with grid coupling at different grid bias. H.T., 120 volts; L.T., 1.8 volts; 72.2° F., room; 69° F., cell. Curve A, G.B. 6 volts; Curve B, G.B. 9 volts; Curve C, G.B. 12 volts.*

slight decrease in frequency which now takes place is due to the slight increase of $-M$ in the large term in the denominator as the coupling is increased.

The conditions of the circuit were now standardised so that there would be as few variables as possible at one time. The H.T. was made 120 volts (the dial boxes allowing for the required variations in anode potential), and in view of the appreciable grid current the grid bias was increased. With large grid bias the critical value of M is raised, due to increase of anode resistance, and the oscillator would only oscillate over a small range of variation of grid coupling.

At 15 volts G.B., 120 volts H.T., it would only oscillate above the 12 cms. setting; *i.e.*, $M > 92$ mH.'s.

At 6 volts G.B., 120 volts H.T., it would oscillate as before above the 9.5 cms. setting; *i.e.*, $M > 73$ mH.'s (grid current was about 13 μA.).

If we consider the R_g term in the critical M equation as negligible at 15 volts G.B. and work out the value of R_a corresponding to a critical value of $M = 92$ mH.'s we get 80,800 ohms for R_a; but this is only true if μ remains constant, which it most probably does not. So that the calculation for the new R_a is not of much value. Looking at the D.E.R. characteristic for 120 volts we can see that at 15 volts G.B. the sphere of operations is well out on the bottom bend, and this would cause the average slope $\frac{di_a}{dv_g}$ to be very much decreased, *i.e.* G is decreased, or $\frac{\mu}{R_a}$.

Curves of frequency departure with varying grid coupling are shown for different values of grid bias in Fig. 9. The left-hand end of each curve indicates the point at which oscillation ceased. The curves were all taken at the same temperature, so we see that the effect of a very large grid bias is to decrease the frequency departure from the

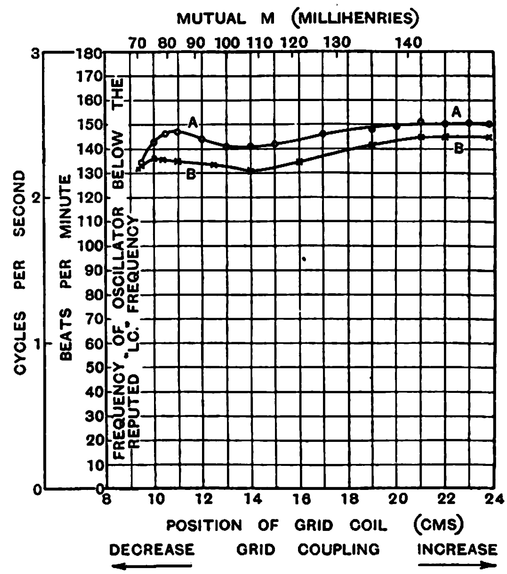


Fig. 10.—*Frequency variation with grid coupling at different temperatures. H.T., 120 volts; L.T., 1.8 volts; G.B., 6 volts. Curve A, 69.5° F. room, 67.0° F. cell; Curve B, 72.2° F. room, 69.0° F. cell.*

"LC" frequency f_0; that is, the frequency of oscillations is slightly higher. This is accounted for when we remember that

both R_a and R_g are larger at the big grid bias value, and this reduces the important term in the denominator and so decreases the frequency departure. Calculation of numerical values becomes difficult when we

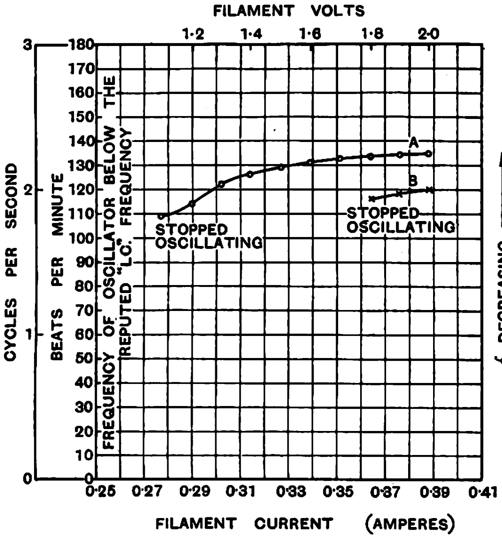


Fig. 11.—*Frequency variation with filament current at different grid coupling. H.T., 60 volts; G.B., 6 volts; 69° F. fork; 72.2° F., room. Curve A, 23 cms. G.C.; Curve B, 13 cms. G.C.*

consider that μ, R_a and R_g are all involved as well as M. The curves indicate that the conditions of larger grid bias lead to a smaller frequency variation.

In the case of a large grid bias curve there seems to be less instability, and readings when repeated proved to be almost identical.

Readings of anode current when oscillating gave :—

3.2 mA.'s at 6 volts G.B.
2.9 mA.'s at 9 volts G.B.
2.4 mA.'s at 12 volts G.B. } 120 volts H.T.

It is suggested that for future work accurate readings be taken of the anode milliammeter, so that every variation is recorded. At the time of taking the measurements the above readings seemed relatively unimportant, but a full set of readings would have given us the oscillating characteristic of the valve, and the R_a changes would have been made clearer when reference was made to both the static and oscillating characteristics.

The curves in Fig. 10 indicate the difference in frequency due to temperature change, for all other conditions were the same for both curves. The frequency difference has been previously dealt with and is accounted for by change in f_0. If the tuning fork temperature had been kept absolutely constant while the room temperature had varied, a conclusive test could have been made as to whether the oscillator frequency was affected by temperature.

(g) *Filament Current.*

Tests were now made with filament current variations instead of grid coupling, and the curves are shown in Fig. 11 for the conditions :—

H.T. volts = 60
Grid Bias = 6 volts.
Room Temperature = 72.2 deg. F.
Fork Temperature = 69.0 deg. F.
Grid Coupling = {(A) 23 cms. and (B) 13 cms.

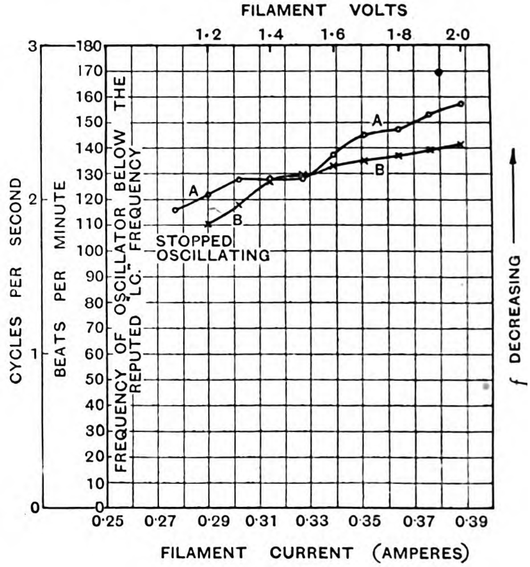


Fig. 12.—*Frequency variation with filament current at different grid coupling. H.T., 120 volts; G.B., 6 volts; 69° F., fork; 72.2° F., room. Curve A, 23 cms. G.C.; Curve B, 12 cms. G.C.*

Two more curves are given in Fig. 12, the conditions being :—

H.T. volts = 120
Grid Bias = 6 volts.
Room Temperature = 72.2 deg. F.
Fork Temperature = 69.0 deg. F.
Grid Coupling = {(A) 23 cms. and (B) 12 cms.

We see that the general tendency is for the frequency to decrease as the filament current increases. R_g decreases as the filament current increases and μ/R_a or G increases, provided that the amplitude of oscillations remains the same. When, however, the amplitude increases to a great extent, G will tend to decrease.

In curve B of Fig. 11, the circuit is only just oscillating, so that probably the amplitude is not forced to a great value, and G does not tend to decrease. Instead, G increases and R_g decreases as the filament current increases, and so $\frac{\mu ML_1}{R_a R_g} \cdot \frac{1}{LC}$ increases and the frequency decreases. The same is the case for curve A in Fig. 11, but more so at first owing to the increased value of M. As the oscillations become stronger the amplitude increases and G tends to decrease and counterbalance the decrease of R_g. The result is that the curve approaches the horizontal. It is probable that the peculiar shape of the curves in Fig. 12 is also accounted for in this manner, the horizontal portion may correspond to reduction in G due to increased amplitude, and the rising portions may correspond to increase in G as the amplitude remains steady for a time, tending to decrease as the filament temperature increases. Again, the frequency change is not so great at the lower coupling value.

(*h*) *Anode Voltage.*

The change of frequency with anode voltage variation is shown in Fig. 13. The conditions were :—

Filament volts	= 1.8
Grid Bias	= 6 volts.
Room Temperature	= 72.2 deg. F.
Fork Temperature	= 69.0 deg. F.
Grid Coupling	= 23 cms.

The oscillations are strong over the whole range, but die off rapidly at 50 volts, so that we may expect a constant value of G right from the time that the oscillations commence at the 50-volt value and the amplitude builds up. But if we look at the characteristic we note that increasing V_a tends to straighten out the curve and so G increases as V_a increases. In addition, R_g increases to a slight extent as V_a increases, and so diminishes the effect of G in increasing the value of the term $G \cdot \frac{ML_1}{R_g LC}$. Hence we should expect only a slight decrease of frequency as anode voltage increases, and this was obtained in the curve in Fig. 13. It would be interesting to see the effect at a smaller mutual value, and also at different values of grid bias ; time, however, did not permit of further curves being taken. The anode current at 50 volts when not oscillating was 0.5 mA., and at 127 volts when oscillating very strongly was 3.4 mA.'s. Unfortunately, other readings were not obtained. Referring to the anode current figures referred to in sub-section (*f*) we see that at 120 volts the horizontal portion of the oscillating characteristic is about 3.3 mA.'s (obtained by

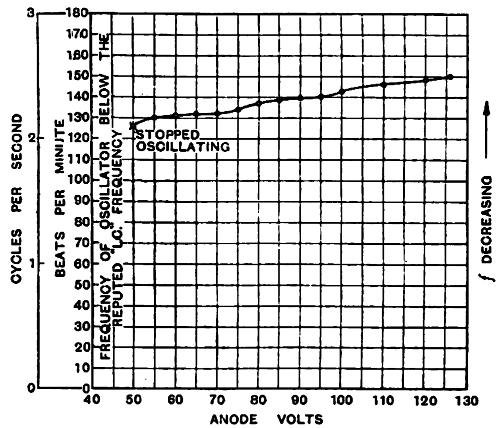


Fig. 13.—*Frequency variation with anode voltage. L.T., 1.8 volts ; G.B., 6 volts ; 72.2° F., room ; 69.0° F., cell ; 23 cms. G.C.*

plotting values given). It would have been useful to know the continuation of this horizontal portion for increasing positive grid potential.

(*k*) *Resistance in the Oscillatory Circuit.*

Curves were obtained by adding non-inductive H.F. resistances in the oscillatory circuit and noting the frequency variation. Curves were taken at two values of grid coupling, viz., 23 cms. (0.145 henry) and 13 cms. (0.1 henry). If R were the only alteration we should expect an increase in frequency, but from the maintenance equation : $M = -\frac{1}{\mu}\left(CRR_a + L + \frac{M^2 R_a}{LR_g}\right)$, we see that if R increases, then to maintain the

critical M at the same value a reduction must take place in R_a: this is accomplished by a reduction in the amplitude of oscillations. The result is that the frequency decreases due to the increase in the large term of the denominator of the equation 7. A reduction of the amplitude probably reduces the grid current and so increases R_g with further increase of R; this tends to diminish the decrease in frequency, thus producing the horizontal portion of the curve. With still further increase of R, decrease of amplitude brings about no further reduction of R_a or increase of R_g, and so the critical value of M is not satisfied and oscillations cease.

The curve taken with a smaller grid coupling (13 cms.) indicates a higher frequency, as might be expected from foregoing results, and also indicates cessure of oscillation at a lower value of added resistance than in the case of the higher coupling (23 cms.). The frequency departure was too large to count above 70 ohms added resistance, so that actual value of added resistance at which oscillations ceased was not obtained for the higher coupling curve. The curves indicate how careful one must be in estimating frequency changes, to consider all the variations which are likely to take place. The general tendency would have been to expect a frequency increase owing to the term $\left(1 + \frac{R}{R_a}\right)$, and the more important term in the denominator not involving R might have been neglected. The effect of increasing grid bias and so increasing R_g to a large value would have been interesting to see, and it is expected that the slope of the curve would in consequence have been diminished or even reversed. Once again the effect of grid bias in reducing frequency variation is brought to light. The difficulty in making tests as desired above, lies in making the oscillator oscillate under non-favourable conditions. In this connection it would have been more suitable to have adopted a higher frequency than 640 cycles, say, 896 or 1,024 cycles, for the oscillator was more suitable for oscillating at such higher frequencies.

V.—Conclusion.

(*a*) *Criticism of the Method.*

The method has been established as a practical one by the foregoing work, and results are readily obtainable; the investigations do not pretend, however, to be an exhaustive study in the vast field of valve oscillator frequencies, but a large amount of ground has been covered, and the ice broken for further research on this subject. The method is quite a new one, previous investigations being carried out by capacity variations, whereas in this case the practical condition has been satisfied of keeping the "LC" value constant and actually counting the frequency departure as different conditions are imposed. The method has

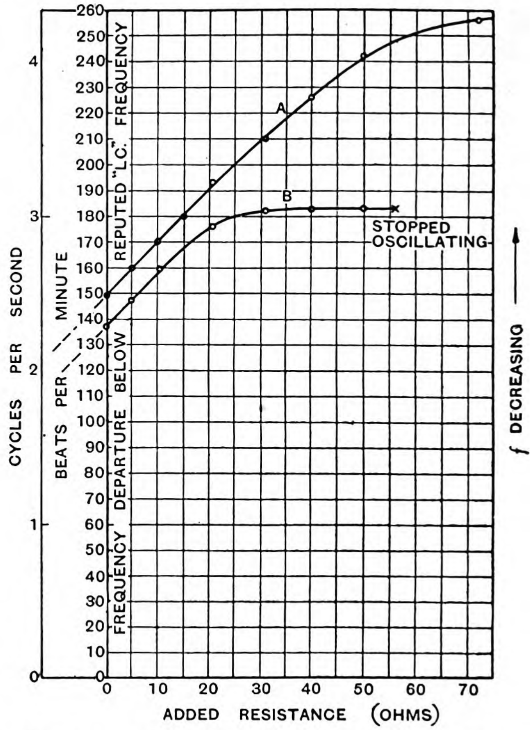


Fig. 14.—*Frequency variation with added resistance in the oscillatory circuit. Va, 120 volts; Vf, 1.8 volts; G.B., 6 volts; 72.2° F., room; 69° F., fork. Curve A, 23 cms. G.C.; Curve B, 13 cms. G.C.*

proved that the actual frequency variation can be determined very accurately. By taking one minute over each reading we can determine small changes of the order of 1 beat per minute if conditions are made suitable, *i.e.* $\frac{1}{60}$ cycle in 640, or 1 in 40,000 change. Hence we see the desirability of a constant frequency source which

TABLE OF RESULTS.

(a) Grid Coupling.

Fig. 7. Cms.	Fig. 7. Bts./Min.
9.5	150
10	157, 159, 157
10.5	163
11	165
12	166, 163
13	160
14	158
15	154, 155, 155
16	155.5
17	157
18	159
19	159
20	162
21	162
22	162

Fig. 10A. Cms.	Fig. 10A. Bts./Min.
9.5	134
10	143
11	147
12	144
13	141
14	141
15	142
17	146
19	148
20	149
21	151
22	150
23	150.3
23.8	150

Figs. 10B/9A. Cms.	Figs. 10B/9A. Bts./Min.
9.4	132
9.5	133
10	136
10.4	135.2
11	135, 136
12.5	133.2
14	131
16	134.5
19	141.5
21	145
22	145
23.8	145

Fig. 9B. Cms.	Fig. 9B. Bts./Min.
—	—
10.5	123
12	133
14	134
15	134
16	137
17	140
19	142, 141
21	144
23.8	144.5

Fig. 9C. Cms.	Fig. 9C. Bts./Min.
—	—
12.3	122
13.	130
14	132.5
15	135
16.5	136
17.4	138
18	138, 139
19	141
20	141
21	141.2
23.8	141.5

(b) Anode Voltage.

Fig. 13.	Volts	127	127	120	110	100	100	95	90	85	80
	Bts./Min.	152	150	148	146	142.5	143.5	140	139.5	138.5	136.5
	Volts	80	75	70	65	65	55	60	60	52	50
	Bts./Min.	137.5	134	132	133	132	130	131	130.5	124	126

(c) Filament Voltage.

Fig. 11A.		Fig. 11B.		Fig. 12A.		Fig. 12B.	
Volts.	Bts./Min.	Volts.	Bts./Min.	Volts.	Bts./Min.	Volts.	Bts./Min.
1.1	109	—	—	1.1	116	—	—
1.2	114			1.2	121.5	1.2	110
1.3	122			1.3	127.5	1.3	118
1.4	126			1.4	128	1.4	127
1.5	129			1.5	128	1.5	129
1.6	131			1.6	137	1.6	133
1.7	132.5	—	—	1.7	145	1.7	135
1.8	133.5	1.8	116	1.8	147.2	1.8	137
1.9	135	1.9	118.5	1.9	153	1.9	139
2.0	135	2.0	120	2.0	157	2.0	141.3

(d) Resistance Adding.

Fig. 14A.	Ohms	0	5	10.36	15.36	20.75	31	41.67	50	72
	Bts./Min.	149	160	170	180	193	205	226	242	256
Fig. 14B.	Ohms	0	5	10.36	—	20.75	31	41.67	—	—
	Bts./Min.	137	147	159	—	176	182	183	—	—

can be relied upon to 1 or 2 parts in 100,000. While there has been little doubt in the accuracy of the recorded frequency variation, there has been some doubt over the actual value of the frequency departure from the "LC" frequency, or, in other words, over the exact location of the base line in the curves, and this has been thoroughly dealt with in the article. Numerical values have been introduced in some cases to account for the practical results from the theoretical point of view, but in most cases these are not relied upon owing to complications arising from variations of R_a, R_g, and μ, and the consequent uncertainty in their actual value; they do agree, however, to a rough extent with the practical results. It is to be regretted that the oscillator was not worked at a higher frequency, so that variations of a greater range could have been imposed without causing the oscillations to cease.

(*b*) *Suggestions for Further Research*.

In the article various suggestions have been made on certain points in which experience has indicated the necessity for certain precautions or modifications. The chief suggestion is that the tuning fork should be of a non-expansible alloy and enclosed in a reliable constant temperature cell fitted with an automatic heat-regulating device. In this way one variable is eliminated and more direct results can be established.

The question as to whether a higher frequency fork is really desirable is a matter of compromise. It will be far easier to maintain the fork, but decidedly more difficult to synchronise the phonic wheel. It is true that only one or two readings would have to be made during which the phonic wheel will have to run, but it may take days or even weeks of trouble just to get these one or two readings. What is required is a light phonic wheel of rigid construction, and a very small air gap between the rotor and stator poles. With a higher frequency fork the output voltage to the motor will be greater, and this will partly make up for the higher voltage necessary at the higher frequency of the motor supply. It is to be hoped that research may be made on the synchronous motor of this type, so that definite information is forthcoming as to the suitability of a distorted wave form or otherwise for the motor supply.

The influence of earth connections on the frequency of the maintained fork should be gone into thoroughly, and it is to be regretted that time did not permit of a further frequency determination at a suitably different temperature and circuit arrangement in the present case.

Emphasis is laid on the necessity for very refined measurements on the L and C values, so that dependable values for the actual frequency departure may be obtained.

In connection with the oscillator tests, there is a vast amount of work to be done. Continuing on this oscillator, the frequency could be increased to about 1,000 cycles, so that a larger range of variations could be imposed without the oscillations ceasing. The anode tap might be introduced arranging for L and C still to give the same value of f_0 the "LC" frequency and comparing with previous results. Following this, the frequency may be increased in stages up to the radio frequencies when new factors such as self-capacity would enter into consideration. Tuned grid circuits may be investigated in the same way. In working out numerical values, a knowledge of R_a and R_g would greatly help. A device in the form of an oscillograph might be arranged so that some idea of the R_a changes can be obtained; also anode current readings should be taken for every test made, and the oscillating characteristic of the valve obtained.

Abstracts and References.

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PROPAGATION OF WAVES.

KURZWELLENECHOS, DIE MEHRERE SEKUNDEN NACH DEM HAUPTSIGNAL EINTREFFEN, UND WIE SIE SICH AUS DER THEORIE DES POLARLICHTES ERKLÄREN LASSEN (Short Wave Echoes arriving Several Seconds after the Main Signal, and How they can be Explained by the Polar Light Theory).—C. Stôrmer. (*Naturwiss.*, 16th August, 1929, Vol. 17, pp. 643–651.)

This consecutive account of the incidents referred to in various previous Abstracts recalls how the writer's "toroidal space" theory led him to prophesy, in the issue of *Nature* for 5th January, 1929, that no more long-time echoes would be heard until mid-February (March Abstracts, p. 144). No echoes were heard until 14th and 18th February, when they were heard by Hals near Oslo, and in Bodö respectively, and on 19th February Appleton and Borrow in London heard echoes with delays up to 25 secs. and lasting over 2 secs. The writer not unnaturally concludes that these results confirm his theory. The rest of the paper deals with an exposition of this theory and the calculations on which it is based. The writer urges international co-operation in investigating the phenomena, on wavelengths other than 31.4 m., oscillographic methods being highly desirable. Observations during the occurrence of polar light and of magnetic storms would be especially valuable. A postscript announces that Ferrié reports numerous long-time echoes in Indo-China during and after the solar eclipse of 9th May. The delays were very often between 15 and 30 secs., and the echoes were sometimes very strong and often multiple.

LONG DELAYED RADIO ECHOES.—P. O. Pedersen. (*Nature*, 27th July, 1929, Vol. 124, p. 164.)

Summary of a paper in English communicated to the Danish Royal Society. According to the writer, Stôrmer, Wagner and he himself believe that the short-wave long-time echoes are caused by reflection from swarms of electrons out in space, whereas van der Pol, Appleton and Ardenne assume that the long delay is due to special conditions in the Heaviside layer, Ardenne assuming that in some cases the waves travel round the earth some hundreds of times. The writer gives mathematical proof to show that the long delayed echoes cannot arise either by the propagation of waves within the earth's atmosphere or by the waves travelling outside the latter in a medium so strongly ionised that the group velocity of the electrons approaches zero. The assumption is made that all waves shorter than about 8 m., will penetrate into space with very little attenuation. At noon, all waves longer than about 40 m. are completely reflected or refracted back to earth. At midnight the waves must be longer than 70 m. to be reflected back. The lengths vary appreciably with the ionisation of the upper atmosphere. The writer concludes that echoes occurring after intervals from 10 up to 30 seconds are probably due to propagation along or reflection from Stôrmer's swarms or bands of electrons in space. In the case of intervals of several minutes, these bands must be outside the space in which the magnetic field of the earth exerts any appreciable direct influence.

PENETRATION OF ROCKS BY ELECTROMAGNETIC WAVES.—A. S. Eve, D. A. Keys, F. W. Lee. (*Nature*, 3rd August, 1929, Vol. 124, pp. 178–179.)

To settle the somewhat conflicting results in the Mount Royal Tunnel tests (May Abstracts, p. 263) where complications were introduced by the presence of wires, rails, etc., more researches were made in the Mammoth Cave, Kentucky. Waves of the broadcasting zone can certainly give good signals under 300 ft. of sand- and lime-stone, without possible entrance by an opening or by conductors. Long-wave stations gave the same bearings above ground and under 300 ft. of rock, so that apparently they travel through rock with front mainly vertical just as through the air. Preliminary results on waves of horizontal front strongly suggest that 20–30 kc. frequencies pass through the rock with much less absorption than 40–100 kc. Using audio-frequencies, it was found that the electromagnetic effects of a 500-cycle frequency passed through 900 ft. of continuous rock. The resistivities of these rocks *in situ* were found by electrical prospecting methods to be of the order of 10,000 to 20,000 ohm/cm.

SUR LA PROPAGATION ET LA DÉTECTION DES ONDES COURTES—10 À 18 CM. (The Propagation and Detection of Short Waves—10 to 18 cms.).—E. Pierret. (*Journ. de Phys. et le Rad.*, No. 2, 1929, Vol. 10, pp. 31 S–32 S.)

Experiments on absorption, reflection, stationary waves, polarisation by wire grids, refraction by paraffin prisms and glass lenses, total reflection, etc., etc. See same author and also Beauvais, March Abstracts, p. 149.

EXPERIMENTS IN RECORDING RADIO SIGNAL INTENSITY.—L. W. Austin. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1192–1205.)

The paper read at the 1928 U.R.S.I. meeting. Author's abstract :—"The paper describes briefly the method of recording the strength of long-wave radio signals used at the Bureau of Standards and gives some of the results obtained. The curves shown indicate the great variability of the wave

propagation both in regard to strength and the angle of incidence of the downcoming wave. This variability appears to be greater for transmission distances below 1,000 km. than for greater distances.

An apparent connection is shown in certain cases between the night signal variations and magnetic storms. The observations seem to indicate that the downcoming waves are reflected (or refracted) from rapidly changing masses of ionized gas," forming an irregular and shifting lower surface and possibly at times thinning out or forming openings so that the rays may then pass to higher levels before being turned back towards the earth. The writer adds, however, that there is a difficulty in accepting this conception, as it would seem to imply the occurrence of rays striking the receiving system at times from the side which is not in the great circle plane joining the sending and receiving stations: "such rays would produce deviations in direction finding of a type which, according to the experiments of Smith-Rose with the Adcock direction-finder, should not exist."

RADIO RECEPTION AND SUN SPOTS.—H. T. Stetson: G. W. Pickard. (*Sci. News-letter*, 3rd August, 1929, Vol. 16, pp. 59–61.)

A popular article based on interviews with the two workers named. The fifteen-month sun-spot maximum is due about October, when broadcast reception will be as poor as in July, 1928. The 11-year general minimum is due in 1934, when reception will be exceptionally good, as it was in 1923—when broadcasting was first coming into popularity. But with certain wavelengths, solar activity improves rather than spoils reception, as Pickard has observed on 18-kilocycle waves. The effect of direction of travel is referred to briefly.

RELATION OF RADIO WAVE PROPAGATION TO DISTURBANCES IN TERRESTRIAL MAGNETISM. —I. J. Wymore. (*Bur. of Stds. Journ. of Res.*, June, 1929, Vol. 2, pp. 1201–1211; also *Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1206–1213.)

See September Abstracts, p. 500. Author's summary:—" . . . The results show that for long-wave daylight reception over great distances (4,000–7,100 km.) there is, in general, a variable but definite increase in the intensity of the received signal following the height of severe magnetic disturbance. This increase reaches its maximum in from one to two days and disappears in from four to five days. For moderate distances (250 to 459 km.) there is an increase in the intensity of the received signals noticeable before as well as after the magnetic storm reaches a maximum. These changes in intensity cover periods from two to four days, both before and after the magnetic storm reaches its height." This summary does not very clearly correspond with the statements in the paragraph previously abstracted; but at the end of the paper, after giving a number of curves, the writer says that as regards low-frequency waves (15–24 kc.), daylight signals tend to behave as follows:—over long distances the intensity falls below normal for several days before the maximum magnetic disturbance, which is followed by a definite increase in strength from one to four days after the storm; over moderate distances there is an increase above the average strength from two to four days before the disturbance with values below normal during the height of the storm, followed by a strong increase from two to four days after the storm.

EAST-WEST AND NORTH-SOUTH ATTENUATIONS OF LONG RADIO WAVES ON THE PACIFIC.—E. Yokoyama and T. Nakai. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1240–1247.)

Authors' summary:—A comparative study of low-frequency signals of high power stations in the Pacific area has been made, with particular reference to relative attenuation in north and south directions as compared with attenuations in east and west directions. A comparison of observed field strengths in microvolts per meter with the results calculated by various proposed formulas has been made. While the agreement is none too good with any of the formulas, the results indicate that east and west attenuation is decidedly greater than north and south during the daylight hours in the fairly high latitudes. They also indicate that in comparing observed results with different transmission formulas, due account must be taken of the type of experiments upon which the formulas in question were based. It is suggested that by the inclusion of terms in the formulas, depending upon both direction and latitude, it might be possible to construct or modify some of the existing formulas to fit the general case.

THE MEASUREMENTS OF THE FIELD INTENSITIES OF SOME HIGH-POWER LONG-DISTANCE RADIO STATIONS. IV.—Warsaw, Tananarive and Monte Grande.—E. Yokoyama and T. Nakai. (*Electrotech. Lab.*, Tokio, April, 1929, No. 258, 78 pp.)

FIVE-METER WORK.—C. H. West. (*Rad. Engineering*, June, 1929, Vol. 9, pp. 53–56.)

In the course of this article the writer describes some experiments tending to show that sunlight, or powerful artificial light, affect the transmitting aerial so that the transmitter radiates more energy than when the aerial is in darkness. Alternatively, he seems to suggest that possibly sunlight causes a change in the wavelength radiated.

ÜBER DIE AUSBREITUNG ELEKTRISCHER WELLEN UM EINE LEITENDE KUGEL (The Propagation of Electric Waves on a Conducting Sphere).—F. Breisig. (*E.N.T.*, July, 1929, Vol. 6, pp. 268–271.)

A defence of the main points of Kiebitz' theory of the propagation of waves over the earth's surface, which was condemned by Mesny and by Willstädter on the grounds that (while correct in its mathematical development) it led to consequences which were contradicted by fact. The writer attacks the question in a different way and arrives at the same results as those reached by Kiebitz, *e.g.*, for a point in or near the surface of the sphere,

$$\overline{|\mathfrak{E}|} = \frac{\omega^2 Q l}{\sqrt{2} \cdot p}$$

where l is the length of dipole and Q its charge.

A STUDY OF THE VERTICAL GRADIENT OF TEMPERATURE IN THE ATMOSPHERE NEAR THE GROUND.—N. K. Johnson. (*Geoph. Mem. of the Met. Office*, No. 46, 1929.)

The construction, use and results are described of an apparatus for measuring the temperature at three levels up to 17 metres from the ground. The writer, from his observations, supports Chapman's conclusion (from Eiffel Tower observations) that the temperature changes are largely influenced by long-wave radiation.

ON THE CRITERION FOR STABILITY OF A LAYER OF VISCOUS FLUID HEATED FROM BELOW.—A. R. Low. (*Proc. Roy. Soc.*, 1st August, 1929, Vol. 125A, pp. 180–195.)

LA FILTRATION DU RAYONNEMENT SOLAIRE PAR L'OZONE ATMOSPHÉRIQUE (The Filtration of Solar Radiation by Atmospheric Ozone).—G. Déjardin. (*C. R. Séance. Soc. de Phys. de Genève*, No. 1, 1928, Vol. 45, pp. 43–44.)

The writer's Mont Blanc observations lead to the height of about 45 km. for the most concentrated region of the absorbing substance (which between λ3500 and λ3090 appears to be ozone). Below λ2100 he concludes that the absorption is by layers of oxygen.

FORMATION OF OZONE IN ELECTRICAL DISCHARGE AT PRESSURES BELOW 3 MILLIMETRES.—J. K. Hunt. (*Journ. Am. Chem. Soc.*, January, 1929, Vol. 51, pp. 30–38.)

Among the results of these experiments may be mentioned:—the highest yield was 26 gm. per kw.-hour: a calculation on the basis of ionisation potentials indicated that the number of pairs of ions and the number of molecules of ozone produced were of the same order of magnitude, suggesting that the predominating mechanism of ozone formation may be one involving collision between monatomic oxygen ions and neutral molecules.

THE ALTITUDE OF THE OZONE LAYER.—J. C. McLennan, R. Ruedy, and V. Krotkov. (*Roy. Soc. Canada*, May, 1928, Vol. 22, pp. 293–301.)

The heights found are slightly higher than those given by Cabannes and Dufay.

MESSUNGEN DES OZONGEHALTES ÜBER LINDENBERG (Measurements of Ozone Content over Lindenberg).—P. Duckert. (*Beitr. z. Phys. d. freien Atmos.*, No. 4, 1928, Vol. 14, pp. 219–239.)

A summary, quoting some values obtained, is in *Physik. Ber.*, 15th May, 1929.

RELATIONS ENTRE LES TITRES EN OZONE DE L'AIR DU SOL ET DE L'AIR DE LA HAUTE ATMOSPHÈRE (Relations between the Ozone Values of Air at Ground Level and of Air of the Upper Atmosphere).—A. Lepape and G. Colange. (*Comptes Rendus*, 1st July, 1929, Vol. 189, pp. 53–54.)

Measurements at ground level at Paris from 1875 to 1908 would give (if the proportion were supposed to be constant throughout the atmosphere) an equivalent layer 1–2 hundredths of a millimetre thick. Measurements in the upper atmosphere at Arosa in 1927 give 2–3 mm. In spite of the great difference thus indicated between the ozone values at the two levels, the two sets of observations are intimately connected, both showing an annual variation with a maximum in the spring and a minimum in autumn. A table of comparative values shows this relation. The authors conclude that if it is admitted that the layers of the upper atmosphere only mix very slowly with the troposphere, it seems that the lower layers of the stratosphere must contain appreciable quantities of ozone. Accordingly, measurements of the height of the ozone layer (40–50 km.—Cabannes and Dufay) merely indicate a maximum of the ozone content. The writers stress the important need of simultaneous observations at the *same* station of the values at the two levels, with a view to establishing a still closer relation.

VELOCITY OF LIGHT AND THE RATIO OF E.S. AND E.M. UNITS. (*See* Curtis, under "Measurements and Standards.")

DIE BESTIMMUNG DER LICHTGESCHWINDIGKEIT UNTER VERWENDUNG DES ELEKTROOPTISCHEN KERREFFEKTES (Determination of the Velocity of Light by the Use of the Electro-optical Kerr Effect).—O. Mittelstaedt. (*Ann. der Phys.*, 15th July, 1929, Series 5, Vol. 2, No. 3, pp. 285–312.)

By the latest compensation method the value comes out at 299778 km./sec. with a possible error of $\pm$20 km.

THE INFLUENCE OF AN ALTERNATING FIELD ON LIGHT TRANSMITTED THROUGH WATER.—W. F. G. Swann: A. Bramley. (*Journ. Franklin Inst.*, August, 1929, Vol. 208, pp. 222–228.)

SABINE'S LAW IN RELATION TO ELECTROMAGNETIC RADIATION IN CLOSED SPACES.—M. J. O. Strutt. (*See* under "Acoustics.")

THE MOBILITY DISTRIBUTION AND RATE OF FORMATION OF NEGATIVE IONS IN AIR.—J. L. Hamshere. (*Proc. Cambridge Phil. Soc.*, April, 1929, Vol. 25, Part II, pp. 205–217.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

ÜBER DIE FORTSETZUNG DER GENEROSO-VERSUCHE (On the Progress of the Mt. Generoso Experiments).—A. Brasch, F. Lange and C. Urban. (*Naturwiss.*, 5th April, 1929, Vol. 17, p. 228.)

These experiments on the obtaining of enormous voltages from the atmosphere during storms in Switzerland were referred to in Abstracts, 1928, Vol. 5, pp. 462 and 586 (Nernst). Latest results are the production of 18 metre sparks, corresponding to some thousands of amperes at voltages of about 8 million; apparently greater values still could

have been obtained if a larger spark-gap had been available, with corresponding increase of insulation. But the writers consider that the present results are good enough for their purpose—tests on atomic disintegration. The problem of designing discharge-tubes to utilise the available power remains to be solved; at present, tests have been made with various tubes up to one million volts.

Contribution à l'Étude de la Matière fulminante (Contribution to the Study of Fulminant Matter).—E. Mathias. (*Comptes Rendus*, 27th May, 1929, Vol. 188, pp. 1355–1358.)

A new theory on the nature of lightning, ordinary and globular, which explains the failure of the usual lightning-conductor to protect against the latter. The "fulminant matter" of the ordinary flash decomposes instantaneously on contact with the conductor, while that of globular lightning—being comparatively cool and conducting heat and electricity only moderately well—is not thus dispersed. Its spherical shape, also, only gives a point contact with the conductor.

Spark Potentials at Pressures below Atmospheric Pressure, and the Minimum Potential with respect to the Electrode Function.—F. Klingelfuss. (*Zeitschr. f. Phys.*, December, 1928, and January, 1929, Vol. 52, Nos. 9/12, pp. 746–747 and 890–891.)

Measurements of Atmospheric Electricity.—G. Aliverti and A. Rostagni. (Summary in *Science Abstracts*, Sec. A, 25th May, 1929, Vol. 32, p. 452.)

Charges of Thunder Clouds.—D. Nukiyama and H. Noto. (*Ibid.*, p. 453.)

La Foudre et les Lignes Électriques (Lightning and Electric Lines).—C. Dauzère. (*Bull. d.l. Soc. Franç. d. Élec.*, June, 1929, Vol. 9, pp. 575–598.)

One of the conclusions reached is that the approach and beginning of a storm are characterised by an increase in the total number of ions, positive and negative, per cubic centimetre of air, and by the predominance of the negative ions. It is also concluded that protective measures need not in general be taken all along a line; it is enough to localise them at the spots where lightning is likely to strike (see Abstracts, 1928, Vol. 5, p. 517). These spots should be avoided in planning a new line.

Some Thundercloud Problems.—C. T. R. Wilson. (*Journ. Franklin Inst.*, July, 1929, Vol. 208, pp. 1–12.)

New Use for Fultograph.—(*Elec. Review*, 9th August, 1929, Vol. 105, p. 240.)

A paragraph on the special transmission now being carried on by collaboration between the B.B.C. and the Radio Research Board Station at Slough, for the recording of atmospherics on Fultograph receivers installed at various points over Britain and the Continent. Pictures of "squared paper" are broadcast, and any atmospherics occurring during the transmission will be recorded. Since the drums of all the receiving sets will be running in synchrony, it will be possible, by comparing the results at the different places, to get valuable information as to the range of an individual atmospheric and as to the intensity of such interference in different localities.

Correlation of Directional Observations of Atmospherics with Weather Phenomena.—S. W. Dean. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1185–1191.)

The full paper, a report of which was dealt with in August Abstracts, pp. 444–445. The Houlton work was inspired by the similar observations of Watson Watt and his associates in England and Scotland, using a telephone connection between distant observation points. The same type of apparatus (cathode ray d.f.) was used at Houlton, and in spite of there being only a single station available, so that the triangulation obtained by the British workers was impossible, it was possible in the vast majority of cases to correlate the observations with weather conditions. Bi-directional ambiguity of the d.f. was removed by the installation of "a uni-directional feature."

Some Measurements on the Directional Distribution of Static.—A. E. Harper. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1214–1224.)

The full paper, a report of which was dealt with in August Abstracts, p. 444. A photograph, but no description, is given of the cathode ray d.f. modified to make it unidirectional "and to increase its ease of operation." Charts showing world-distribution of thunderstorms are reproduced from a British Air Ministry Memoir, and special charts for the United States are also given.

Weather Analysis Associated in Three Dimensions. Part I.—Main Introduction to the Problem of Air Masses and Front Formation.—T. Bergeron. (*Geofys. Publ. Oslo*, 5.6. 1928, 111 pp.)

Die Messung der Horizontal- und der Vertikalintensität des erdmagnetischen Feldes mit dem Magnetron (The Use of the Magnetron for Measuring the Horizontal and Vertical Intensities of the Earth's Magnetic Field).—M. Rössiger. (*Zeitschr. f. Instr:kde*, No. 3, 1929, Vol. 49, pp. 105–113.)

L'Hyperatmosphère électrique et le Magnétisme terrestre (The Electric Hyperatmosphere and Terrestrial Magnetism).—D. Grave. (*Bull. Acad. Sci. Leningrad*, No. 4/5, 1928, pp. 347–366.)

After a preliminary exposition of the relations between sunspots and terrestrial phenomena, the writer attempts to explain the known aberrations of the solar system from the Newtonian mechanics by the help of the assumption of an electrical (solar) hyperatmosphere. Variations of the earth's

magnetism are explained by an external, variable component originating in this hyperatmosphere.

ROTATION OF THE EARTH AND MAGNETOSTRICTION.—E. S. King; A. H. R. Goldie. (*Nature*, 5th January and 24th August, 1929, Vols. 123 and 124, pp. 15 and 303.)

Letters on a possible relation between changes in the rate of the earth's rotation and changes in the magnetic declination.

THE SPECTRUM OF SUNLIT AURORA RAYS AS COMPARED WITH THE SPECTRUM OF LOW AURORA IN THE EARTH'S SHADOW.—Carl Störmer. (*Nature*, 17th August, 1929, Vol. 124, p. 264.)

The writer gives a preliminary announcement of results of observations in which he finds that the green auroral line 5577, which is very strong for the common aurora in the earth's shadow, is very much fainter for high sunlit aurora, as compared with the lines of ionised nitrogen 4728 and 3914. No lines of helium or hydrogen seem to occur in the spectrum of these high rays. The observations were made at a time when the Swedish Telegraphy Services were being disturbed by earth currents.

AN ENDEAVOR TO DETECT A CORPUSCULAR CURRENT ENTERING THE EARTH.—W. F. G. Swann and A. Longacre. (*Journ. Franklin Inst.*, August, 1929, Vol 208, pp. 275–282.)

This extension of an earlier investigation leads to the following conclusion:—that the absolute magnitude of the current absorbed by the copper cylinder employed is not more than 0.25 per cent. of that which would have been obtained by the complete absorption of a vertical corpuscular current density sufficient to account for the replenishment of the earth's charge.

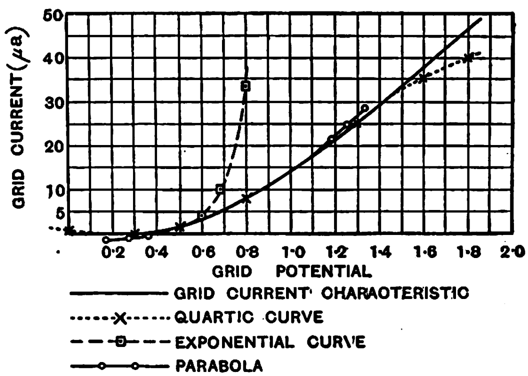
The paper is preceded by one by Swann on the theory of the charging effect on an insulated body exposed to primary corpuscular radiation or to corpuscular radiation initiated by the cosmic radiation.

PROPERTIES OF CIRCUITS.

AN ANALYSIS OF TRIODE VALVE RECTIFICATION.—S. E. A. Landale. (*Proc. Cambridge Phil. Soc.*, July, 1929, Vol. 25, pp. 355–367.)

The writer remarks that Colebrook's treatment of the foot of the grid current curve, as approximating very closely to an exponential form, generally gives fairly accurate results for high temperature cathodes provided that $E + V$ is negative [V being the mean grid potential when an alternating voltage E is applied]. With thoriated or oxide-coated filaments run at a comparatively low temperature, however, the velocity of ejection of electrons is small, and experience shows that the curve has an exponential form only over so restricted a range that Colebrook's analysis is of little practical use. The writer has examined the foot of the curve of many dull filament valves and has found that it can be represented with great accuracy over a considerable range by a quartic equation. The coefficients of the quartic change widely for different valves, and also with age for the same valve, but nevertheless the range of applicability of the quartic is roughly constant for all triodes. As can be seen from one of the diagrams given (*see* below) the exponential curve is fairly accurate up to 0.6 v., and so is the parabola from 0.4 to 1.2 v.

Expressions are given for calculating rectified current and the amplitude of harmonics produced by a *simple* [not cumulative] grid rectifier when



voltages of the following wave-forms are applied: $E \sin pt$, $(A + B \sin nt) \sin pt$, and $(A + B \cos mt + C \cos nt) \sin pt$. Further, a formula is given from which may be calculated the rectified current produced by a cumulative grid rectifier when a voltage $E \sin pt$ is applied.

All these formulæ are applicable if the grid characteristic is parabolic, cubic, quartic or quintic in form.

It is also shown that when an acoustically modulated r-f voltage is applied to a cumulative grid rectifier, even if the valve has a parabolic grid characteristic, an infinite number of harmonics of the modulation frequency are produced, which are due to the action of the grid leak and condenser. It appears, however, that in practice the amplitude of these harmonics will be very small compared with those produced, primarily, by the curvature of the grid characteristic.

REDUCTION OF DISTORTION IN ANODE RECTIFICATION.—A. G. Warren. (*E.W. & W.E.*, August, 1929, Vol. 6, pp. 425–437.)

The writer considers that although in modern loud-speakers the frequency response is by no means perfect, the more serious distortion which still persists in such loud-speakers is due to the presence in the reproduction of alien tones (enharmonic and harmonic) which render the reproduction unduly "stringy" and are introduced chiefly during rectification. He maintains that the reduction of this distortion due to rectification cannot be accomplished by the use of input grid potentials of the magnitudes usually advocated, 1 or 2 volts R.M.S., since over such a range the distortion is almost constant—it may even increase slightly with growth of the alternating grid potential; but that with a properly chosen grid bias and the use of grid-swings far in excess of those generally contemplated, the distortion can be reduced almost to

vanishing point. He advocates a peak value of swing of the order of 10 v., giving (with an average valve) a l-f output of about 7 v. The subsequent l-f amplification must be less than that usually adopted, part of the process of amplification being transferred to the ante-detector stages.

DETECTION AT HIGH SIGNAL VOLTAGES. PART I.—PLATE RECTIFICATION WITH THE HIGH-VACUUM TRIODE.—S. Ballantine. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1153–1177.)

After a preliminary exposition of the problem of linear detection at high signal voltages, the writer deals with his experimental study leading to the design of valve detectors capable of dealing with signal voltages of the order of 10 v. and upwards. Such valves may actually replace the output valve and operate the loud-speaker directly. This may properly be called "Power Detection"; a less extreme step consists in eliminating one audio stage, retaining the power valve [*see* Tanner, Sept. Abstracts, p. 510]. The need (for selectivity's sake) of a certain minimum number of tuned circuits, and the availability of tetrodes with an amplification of the order of 100 for these circuits, render the productions of these high signal voltages quite practicable. The signal voltage can be maintained at the optimum point of the characteristic either by automatic volume control or by manual control facilitated by extending the linear range of the detector by special devices which will be described in the fourth part of the series: other parts will deal with grid, grid-and-plate, diode and crystal rectification, all for high signal voltages.

RIVELAZIONE PER CARATTERISTICA DI GRIGLIA (Detection by Grid Characteristic).—M. Boella. (*Elettrotec.*, 5th August, 1929, Vol. 16, pp. 510–516.)

A description, fully illustrated by curves, of tests of detector efficiency of triodes under various conditions of functioning, when the signals have a considerable intensity, *e.g.*, produce an a-c grid voltage above 0.2 to 0.3 v.

DAS RAUMLADENETZROHR ALS RÜCKGEKOPPELTER WIDERSTANDVERSTÄRKER IN THEORETISCHER BEHANDLUNG (The Space-Charge Valve as Resistance Amplifier with Reaction).—H. G. Baerwald. (*Arch. f. Elektrot.*, 15th July, 1929, Vol. 22, No. 3, pp. 325–336.)

A theoretical investigation to determine the design of such an amplifier, how to obtain effective compensation and what its limits are, and what precautions must be taken for stability. Among the section headings are:—The non-linearity produced by the grid space-charge: an equivalent circuit for the linearly functioning space-charge-grid valve: elementary amplification formulæ for the resistance-coupled s-c-g valve: circuit-values for the saturated and unsaturated valve—comparison of amplification: the influence of filament temperature variations—superiority of the oxide-coated filament: the influence of non-linearity on stability—prediction from static characteristics: dependence of amplification on frequency and its "natural" compensation (a strong point in comparison with a two-valve reaction amplifier): a numerical example indicates that by suitable design the type in question can be made an efficient aperiodic h-f amplifier.

PUSH-PULL AMPLIFICATION: THE USE OF RESISTANCE-CAPACITY COUPLING.—F. Aughtie: P. G. Davidson. (*E.W. & W.E.*, August, 1929, Vol. 6, pp. 437–438.)

Referring to Aughtie's paper (Sept. Abstracts, p. 505) Davidson considers that the advantages there claimed for the arrangement do not include the most important ones, which in his opinion are (1) elimination of back-coupling through h-t supply, from *both* stages of l-f; (2) h-t for all four l-f valves may be taken direct from d-c mains without smoothing; (3) wave-form distortion due to characteristic curvature is cancelled out in the output stage. The writer uses a slightly different arrangement from those suggested by Aughtie, connecting a high resistance potentiometer (such as are used for volume control) between the two anodes V_1 and V_2 and taking the slider to the grid of V_2 through the usual condenser.

DOUBLE-VALUED CHARACTERISTICS OF A RESISTANCE-COUPLED FEED-BACK AMPLIFYING CIRCUIT.—P. B. Carwile. (*Phys. Review*, No. 2, 1929, Vol. 33, p. 284.)

Summary of an investigation of a resistance-coupled Hartley circuit under such conditions that the setting up of reaction does not affect the amplification factor without reaction. The total amplification is then a simple function of two independent variables. If the back-coupling is increased above a certain value, two points of irreversible instability appear in the input-output characteristic: between these points the characteristic has two branches, giving two possible values of output E.M.F. for every value of input. Explanations of these instabilities, their irreversibility, and double-valued characteristic, are given.

SUL FUNZIONAMENTO DEL TRIODO CON FORTE ACCOPPIAMENTO MAGNETICO A NUCLEO DI FERRO FRA CIRCUITO DI PLACCA E CIRCUITO DI GRIGLIA (On the Action of the Triode with Strong Magnetic Coupling through an Iron Core between Grid and Anode Circuits).—O. M. Corbino. (*Elettrotec.*, 25th July, 1929, Vol. 16, pp. 489–491.)

An investigation of the circuit used by Mazzotto for the production of oscillations of musical frequency, readily varied (Mazzotto's "melodious triode").

THE EFFECT OF REGENERATION ON THE RECEIVED SIGNAL STRENGTH.—B. van der Pol. (*Proc. Inst. Rad. Eng.*, February, 1929, Vol. 17, pp. 339–346).

A reprint of the paper dealt with in Abstracts, 1928, Vol. 5, p. 638. The present version is free from certain ambiguities in symbolisation, etc. which occurred in the original paper.

THE TUNED GRID CIRCUIT: PARALLEL CHOKE FEED CIRCUIT IN H.F. AMPLIFIERS.—A. L. M. Sowerby. (*Wireless World*, 10th July, 1929, Vol. 25, pp. 24–26.)

GOOD RADIO REPRODUCTION (ANODE-FEED RESISTANCE SYSTEM).—(*Elec. Review*, 3rd May, 1929, Vol. 104, pp. 807–808.)

The claims of this system to be an important means of minimising the feed-back tendency of receivers (and the consequent distortion) are set out. The use of audio-frequency chokes instead of resistances is discussed. The development of the system is attributed largely to the Ferranti Company.

THE DESIGN OF WAVE FILTERS.—W. Proctor Wilson. (*Marconi Review*, July, 1929, No. 10, pp. 15–25.)

First part of a series by a B.B.C. engineer. "While professing no claim to originality, it is believed that this collection of material will be found to present, in a succinct form, much valuable data of use to the practical engineer interested in filter work from the Radio view-point."

FREQUENZRÜCKKOPPLUNG (Frequency Reaction).—H. E. Hollmann. (*E.N.T.*, July, 1929, Vol. 6, pp. 253–264.)

In normal circuits, reaction is a matter of energy interchange and involves a swinging to-and-fro of amplitudes, the frequency remaining constant. In certain circuits, however, an analogous swinging to-and-fro of frequency takes place, which has essential points in common with the former phenomenon (*e.g.*, the need for a "canal" for the reaction: the effect of damping, etc.) and which the writer designates "frequency reaction." He deals first with the case of electron oscillations in a retarding field (Barkhausen-Kurz circuit) and passes on to the audio-frequency relaxation oscillations (glow-discharge tube) of van der Pol and the multivibrator oscillations of Abraham and Bloch. In the first two examples, the frequency increases with the reaction ("positive" frequency reaction) while in the multivibrator it decreases ("negative" frequency reaction). But if the voltage vector introducing the reaction is rotated 180°, this negative reaction is converted into positive. The paper ends with the description and illustration of a hydrodynamic model representing all these types of oscillation.

PHASE COMPENSATION. I.—A SIMPLE ACCOUNT. II.—DESIGN OF PHASE COMPENSATING NETWORKS. III.—THE NYQUIST METHOD OF MEASURING TIME DELAY.—E. K. Sandeman, A. R. A. Rendall, Sandeman and I. L. Turnbull. (*Elec. Communication*, April, 1929, Vol. 7, pp. 309–330.)

FORCED UNDAMPED ELECTRIC OSCILLATIONS IN COUPLED CIRCUITS.—A. Petrowsky. (*Trans. Elec. Lab. Leningrad*, No. 5, 1927, 227 pp.)

In Russian. Divided into 5 sections:—Analytical treatment of the problem; investigation of the elements characterising the coupled oscillations; vector diagram of undamped oscillations in coupled circuits; investigation of vector diagram; complex resonance (nature and conditions for its appearance: typical cases: magnitudes of currents and voltages: polar diagram: omega and lambda curves).

LES CHARACTÉRISTIQUES ET LA STABILITÉ DES CIRCUITS FERRORÉSONANTS—CIRCUITS OSCILLANTS COMPORTANT DES BOBINES À NOYAUX DE FER (The Characteristics and Stability of "Ferro-resonant" Circuits—Oscillating Circuits including Iron-Cored Coils).—E. Rouelle. (*Comptes Rendus*, 27th May, 1929, Vol. 188, pp. 1392–1394.)

The writer points out certain further developments arising out of Kalantaroff's graphic method of investigating these complex circuits (see June Abstracts, p. 326.)

ERZWUNGENE SCHWINGUNGEN EINES LINEAREN SYSTEMS ZWEITER ORDNUNG (Forced Oscillations of a Linear System of the Second Order).—B. D. H. Tellegen. (*Arch. f. Elektrot.*, 8th May, 1929, Vol. 22, No. 1, pp. 62–80.)

A mathematical and graphic treatment, on the assumptions that the impressed voltage is of simple harmonic form and that the stationary condition has been reached.

TRANSMISSION.

ÜBER BARKHAUSEN-KURZ-WELLEN (Barkhausen-Kurz Waves).—P. Knipping. (*Zeitschr. f. Hochf. Tech.*, July, 1929, Vol. 34, pp. 1–12.)

With a view to clearing up some of the discrepancies between experimental results and the theoretical ideas reached up to the present, the writer has approached the problem from the angle of atomic and electronic considerations, leaving entirely alone the usual questions of steepness of characteristic, reaction coupling, etc. His methods are indicated by his section headings, of which the following are examples:—The various zones at the filament; the position of the "ionisation zone"; the path-time of a H+ ion is equal to that of an electron; the electrons leave the filament in phase: influence of the grid; fate of the H+ ions; extreme vacuum in the neighbourhood of the grid [later on it is pointed out that this effect provides a means of obtaining vacua superior to those given by the best pumps: the latter vacua (*e.g.*, 10^{-8} mm.) contain about 3×10^7 molecules per cm.^{3}, most of which can thus be removed—more quickly and more completely the heavier the molecules. This may explain the success of Pirani's "washing out" of vacuum apparatus with mercury vapour and electrons, and other phenomena]; residual gases other than hydrogen; the effect of changing grid potential on the wavelength; of electrode diameter on the same; of filament current [the more electrons emitted, the further back will the space charge stretch, and with it the ionisation zone: following the writer's previous reasoning, this will cause a shortening of wavelength—as is actually found]; secondary and photo-emission.

From the above it will be gathered that the weight

of the process is laid on the residual gas and its ionisation. This gas is driven, when oscillation is set up, to cathode and anode, the space round the grid being thus rendered free of gas. The primary electrons emerge from the filament in time with the oscillations, and (on account of the extreme vacuum round the grid and the negative double layer at the wires of the grid) swing to and fro through the grid many times [of the order of 1000] before leaving it. With the same periodicity, the space-charge is destroyed by the ions, in such a phase in relation to the electron oscillation that the newly emerging electrons oscillate in phase with the old ones. Certain constants characteristic of the ions, combined with the grid and anode voltages, determine the wavelength, which is entirely independent of capacity and inductance. An emission of 50 MA. corresponds to an oscillating current, between cathode and anode, of no less than 50 A. By virtue of its oscillating anode voltage, the B–K valve behaves as a radiator of zero order, whose space radiation is spherically symmetrical even close to the valve: it thus differs fundamentally from ordinary transmitters. Accordingly, the usually employed Lecher wire system is not adapted to pick up these oscillations, and often gives failing signals at only a metre or two's distance; whereas Barkhausen and Kurz were able, by using a linear oscillator as receiver, to receive telegraphic signals over 600 m. and telephonic over 300 m. *without amplification.*

A section deals with the corresponding actions of electrons and ions in a diode. While a triode gives a more or less sinusoidal characteristic, the diode produces a more " notched " curve.

FREQUENZRÜCKKOPPLUNG (Frequency Reaction).—H. E. Hollmann. (*See* under " Properties of Circuits.")

PRINCIPLES OF THE CALCULATION OF GRID MODULATION.—Kliatskin and Minz. (*T.i T.b.p.*, No. 1, 1929, Vol. 10, pp. 16–32.)

FREQUENCY MODULATION.—N. E. Holmblad: H. Lauer: G. H. Makey. (*E.W. and W.E.*, Aug. and Sept., 1929, Vol. 6, pp. 438 and 499.)

A continuation of the discussion (*see* July and Sept. Abstracts) on the claims of the Westinghouse patent dealt with in *E.W. and W.E.* for March, p. 170.

EENIGE EXPERIMENTEN IN VERBAND MET DE TOEPASSING VAN NIEUWERE TRIODEN-SCHEMÀS BIJ ZENDERS (Some Experiments in connection with the Design of New Transmitting Valve Circuits).—G. W. White. (*Tijdschr. Ned. Radiogenoot,* July, 1929, Vol. 4, No. 2, pp. 17–33.)

In Dutch.

VARIOUS TRANSMITTER PATENTS.—Telefunken Company: J. Fuchs. (*Elektrot. u. Masch: bau,* 11th Aug., 1929, Vol. 47, pp. 691–692.)

Short summaries of a number of Austrian patents, including one in which a number of spaced aerials are fed separately, each by its own group of power amplifier valves; each valve of a group is excited by a common frequency in a different phase, the resulting frequency fed to the aerials being the common frequency multiplied by the number of valves connected to each aerial; the individual aerials are fed in such phase as to produce directional effects.

Another patent deals with telephone modulation by direct grid current; a modulating valve, through which the direct grid current of the valve to be controlled flows, influences the grid potentials of that valve. Since in short wave transmitters the d–c grid current often vanishes, a special " valve " valve is added with its anode connected to the grid of the controlled valve and its cathode to the cathode, while its grid is subjected to the same fluctuations as the grid of the modulating valve. Fuchs' patent concerns a H.F. generator circuit coupled to an intermediate circuit of similar dimensions; the aerial is directly connected to a potential antinode of this intermediate circuit, no earth or counterbalancing capacity being indicated.

OVERZICHT BETREFFENDE DE OPWEKKING VAN ULTRA-KORTE GOLVEN (Survey of Methods of Generating Ultra-short Waves).—B. D. H. Tellegen. (*Tijdschr. Ned. Radiogenoot.*, July, 1929, Vol. 4, No. 2, pp. 34–53.)

In Dutch. Many of the generating circuits are illustrated by diagrams; a very complete bibliography is appended, reaching from 1919 to 1929. *Cf.* Hollmann, June Abstracts, p. 326.

PUSH-PULL SHORT WAVE GENERATING CIRCUIT.—(German Patent 475568, Pohontsch, pub. 27th April, 1929.)

The push-pull circuit is much used for short wave generation in order to obtain the greatest possible symmetry. In the present invention, an oscillating circuit tuned approximately to the required frequency is connected in the lead between the common negative and the mid-point of the common primary of the r-f transformer. A great increase of oscillating power is claimed.

THE GENERATION OF OSCILLATIONS OF CONSTANT FREQUENCY.—(German Patent 475832, Lorenz, pub. 2nd May, 1929.)

If the field winding of a d-c generator is connected to an oscillatory circuit, the generator will produce oscillations dependent in frequency on the circuit and not on the r.p.m. of the machine. If this frequency is low—(e.g., 100 p.p.s.) the losses in the machine will not be excessive. The present patent uses this arrangement in combination with an iron-cored frequency-multiplier.

MULTIPHASE A.C. HIGH-FREQUENCY TRANSFORMER.—(German Patent 475833, Lorenz, published 3rd May, 1929.)

In a system of H.F. generation by feeding a number of valves with multiphase current, high negative anode voltages and positive grid voltages occur during the negative half-cycle, leading to heavy grid currents. To avoid this effect, the grids of each valve are so influenced by the feed

current (by the use of saturated iron-cored rectifiers) that they take on only very small positive potentials or none at all.

RECEPTION.

A REMOTE TUNING CONTROL FOR RADIO RECEIVERS. —W. Faas. (*Rad. Engineering*, March, 1929, Vol. 9, pp. 30–31.)

An automatic tuning system, employing push-buttons, which operates on the gang condensers. It consists of two units—the actuating mechanism which is bolted to the back of the receiver or incorporated in the set itself, and the push-button control unit which includes on-and-off and volume control as well as 8 or more station-selector buttons.

RESISTANCE CONTROL OF REGENERATION.—B. Dudley. (*QST*, August, 1929, Vol. 13, pp. 23–28.)

An investigation into the comparative merits of different circuits embodying resistance control of reaction, and of different commercial variable resistances when used for this purpose. Those of the compressed-carbon type were found to be the best.

SHORT WAVE RECEPTION DIFFICULTIES ON AIRCRAFT. (*See* v. Handel, Kruger and Plendl, below.)

QUARZSTEUERUNG VON KURZWELLEN-EMPFÄNGERN. (Quartz Control of Short Wave Receivers.)—P. v. Handel, K. Kruger and H. Plendl. (*Zeitschr. f. Hochf. Tech.*, July 1929, Vol. 34, pp. 12–18.)

For reception in aircraft. The result of the tests here described may be summed up very briefly :—a quartz-controlled oscillating audion gave a too great decrease in signal-strength and too much sensitivity to vibration, while the use of a quartz-controlled separate heterodyne generator (to give beat-note reception) produced too great difficulties due to slight frequency variations caused by temperature changes, external and internal, which made the note rise to ultra-audibility, in spite of the provision of frequency adjustments. The final solution was the use of a quartz-controlled separate heterodyne generator to give, not beat-note reception, but an intermediate frequency, which was dealt with in a long-wave audion circuit and after rectification was amplified by 2 or 3 stages of l-f magnification. By this plan, special precautions such as thermostats etc. were made superfluous. Moreover, if the aircraft was already provided with a long wave receiver (*e.g.* for d.f.) this could be adapted to the purpose of short wave reception by the addition of an audion circuit and heterodyne generator.

The above results could perhaps have been foreseen, but the paper includes an interesting introductory section on the difficulties of short wave reception on aircraft which led to the experiments. Aeroplane noises could only be combated by raising the strength of signals above the ear's altered threshold of perception—*e.g.* by the addition of another l-f stage. Motor ignition noises proved of only slight importance in the case of the metal aeroplanes used in the tests, and in any case were rendered still less troublesome by keeping the note constant by quartz control of the transmitter. The great trouble proved to be vibration. However carefully the receiver might be suspended, this caused a greater or less spoiling of the heterodyne note ; those receivers which on ground tests had distinguished themselves most for sensitivity and constancy showed themselves most affected, giving signals whose note was so spoiled by vibration effects that they could hardly be distinguished from the background noises. Exhaustive tests showed that the vibration was carried not merely by the suspensions but also by the air ; words spoken near the receiver casing could often be heard clearly in the telephone head-gear. This effect could be overcome by enclosing the receiver in lead or copper, but such a plan involved too great a weight. The careful design of components and the avoidance of connecting wires free to vibrate improved matters, but the effect was so difficult to avoid that of two exactly similar receivers thus carefully designed, one would prove vibration-proof and the other would be sensitive to vibration. Moreover, a perfectly good receiver would in time become sensitive to vibration, or would become so suddenly, on making some small change such as switching from one wave-range to another. Another effect was difficult to cure : if a vibration-proof receiver was tuned to a station and then moved slightly to and fro in its suspension, the heterodyne note would vary in time with its movement, even if the metal container was earthed. Everything, in fact, called for a stabilisation of receiver frequency, since in that case the note would remain pure and constant and only amplitude-variations would remain which would probably not be very serious.

RADIO RECEPTION AND SUN SPOTS.—H. T. Stetson : G. W. Pickard. (*See* under " Propagation of Waves.")

AERIALS AND AERIAL SYSTEMS.

TRANSMITTING ANTENNAS FOR BROADCASTING.—A. Meissner. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1178–1184.)

The paper begins by a short prophecy of future developments in broadcast transmission : frequencies from 20 to 20,000 kc. ; modulation enlarged—ratios of amplitudes of 1 : 1000 are probable, with higher power of transmitter and consequent increased interference ; this may make it necessary to couple many transmitters in groups giving a common programme on a common wave. " This will probably result in control of these transmitters by talking films running synchronously." Higher demands with regard to the reproduction of music may lead to the control of the transmitter without transmission cable between studio and transmitter, and the use of sound records on films operated in the transmitting station.

The rest of the paper concentrates on the transmitting aerial. The increase of the surface waves in proportion to the space waves is being developed in Germany as it is in England : the increased

horizontal radiation resulting from the use of a complete dipole suspended as high as possible instead of a quarter wavelength aerial is illustrated by a curve from the Eckersleys-Kirke paper (April Abstracts, p. 211). The necessity for insulating the high supporting mast at its base and (if it is of metal) for keeping its height below half the emitted wavelength is pointed out: the aerial must be designed so that the centre of capacity of the upper half is still situated at about the same height as in the case of an aerial wire stretched vertically: the length has to be $\lambda/2$. A formula of Beckmann's is quoted for calculating the influence of the mast.

The good results of these high dipoles are illustrated by quoting Eckersley's results and by results obtained by the broadcast transmitter at Budapest, where strength of fields are better than those given by other stations quoted with ordinary aerials, and where fading only begins beyond 150 km.

There still remains to be decided whether a horizontal aerial fed at its centre by a feeder line is better than a vertical aerial.

VERSUCHE ÜBER RICHTANTENNEN BEI KURZEN WELLEN (Experiments with Short Wave Beam Aerials).—W. Moser. (*Zeitschr. f. Hoch. f. Tech.*, July, 1929, Vol. 34, pp. 19–26.)

After preliminary discussion of the problem and of the various ways of dealing with it (Marconi-Franklin Beam, Chireix-Mesny " zig-zag," Meissner parabolic reflector) the paper deals with the Telefunken system of horizontal dipoles (*see* Feb. Abstracts, p. 104, 105, 106).

SYSTÈME FRANÇAIS D'AÉRIENS-PROJECTEURS POUR EMISSIONS SUR ONDES COURTES (French Beam System for Short Waves).—H. Chireix. (*Bull. de la S.F.R.*, May, 1929, Vol. 3, No. 4, pp. 79–96.)

In the course of this paper, dealing with the aerial systems for the Paris—South America service and the Paris—Batavia and Paris—Indo-China tests, the plan is mentioned of raising the aerial network for the day-wave some distance off the ground, utilising the resulting space for the night-wave network.

CALCULATION OF RADIATION RESISTANCE OF ANTENNÆ COMPOSED OF PERPENDICULAR OSCILLATORS.—A. Pistolkors. (*T.i T.b.p.*, No. 1, 1929, Vol. 10, pp. 33–39.)

In Russian.

OM STAVFORMIGA HERTZ'SKA OSCILLATORERS SAMT RÄTLINIGA OCH RINGFORMIGA ELEKTRISKA RESONATORERS EGENSVÄNGNINGAR (On the Natural Wavelengths of Hertz Rod Oscillators with Rectilinear or Cylindrical Resonators).—K. F. Lindman. (*Acta Åbo*, No. 6, 1929, Vol. 5, p. 201S.)

One result is that a hollow cylinder of insulating material enclosing any part of the rod increases the period; the increase is proportional to the length of the cylinder and increases with the wall thickness up to a limit depending on the dielectric constant, but is not appreciably dependent on the position of the cylinder on the rod, or on the original frequency.

A DIRECTIONAL UNTUNED SHORT WAVE RECEIVING ANTENNA.—G. A. Ostroumov. (*T.i T.b.p.*, No. 2, 1929, Vol. 10, pp. 111–124.)

In Russian.

WAVE REFLECTORS AND DIRECTORS.—(German Patent 475293, Yagi, pub. 25th April, 1929.)

The patent covering the directive system of vertical aerials of various lengths, referred to in Abstracts, 1928, Vol. 5, p. 519.

VALVES AND THERMIONICS.

L'ÉTAT ACTUEL DE LA TECHNIQUE DES LAMPES À PLUSIEURS ÉLECTRODES (The Present Position in the Technique of Multi-Electrode Valves).—R. Jouaust. (*L'Onde Élec.*, June, 1929, Vol. 8, pp. 227–261.)

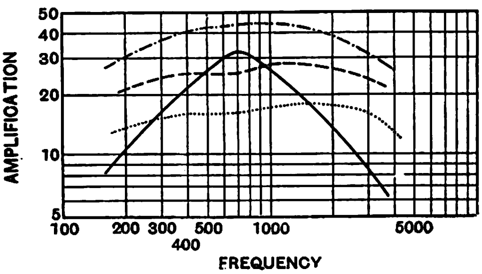
A review of the latest methods of calculation and design of receiving valves. As regards the coefficient of amplification, the writer uses the simplified formulæ given by King in 1920, for flat and cylindrical electrodes; these being derived from the first terms of the series developed from the more complex formulæ of Miller and J. J. Thomson. For the intensities of E.M.F. and current, he uses Kusunose's derivations from Langmuir's formulæ (June Abstracts, pp. 330–331.) He recalls Prince's demonstration that in considering the equivalent diode it is *not* the grid diameter which must be taken as the diameter of the equivalent anode, but the plate diameter of an imaginary triode having the same grid dimensions and unity amplification. He stresses the importance of the ratio anode radius to filament radius in the design of low resistance valves.

Dealing then with inter-electrode capacity and secondary emission, he mentions the results of Le Boiteux, van der Pol, Hull, Farnsworth and Podliasky in connection with the latter, and issues a warning that " the properties of valves based on secondary emission may be strongly modified by a liberation of gas. . . . One must not rely too much on these very fugitive phenomena." He then considers at considerable length the behaviour of electrons in a retarding field such as is produced by a grid potential higher than that of the plate: this leads to the idea of a " virtual cathode " and the work of Lewi Tonks (*Phys. Review*, Oct., 1927). This virtual cathode effect is important from the point of view of the construction of double-grid valves, dealt with in the next section. The writer lays particular stress on the true object of the space-charge grid valve:—it behaves like a diode having for cathode the filament and for anode the inner grid. The plate potential is not involved, and therefore may be very small. The true function of the valve is exemplified by the frame receivers which receive the American stations in France using a plate voltage only 1 v. higher than the positive end of the filament.

The next section deals with the screen-grid valve, beginning with the original idea of Schottky and showing how its revival by Hull was led up to by

Miller's results (which are treated in an appendix). After defining Hull's particular object as the series connection of amplifiers with resonance coupling, the writer examines the possibilities of screen-grid valves for other purposes—e.g. resistance-coupled amplifiers, and concludes that the full benefit of high amplification factor cannot thus be obtained. Moreover, he refers to a result un-noticed by many writers but noted by Decaux—the effect of the plate/screen grid capacity on certain frequencies, to which it may act as a practical short-circuit of the high resistance in the anode circuit.

The final sections deal with the protection of valves against secondary emissions, referring here to power-amplifier valves and transmitting valves (Podliasky, Abstracts, 1928, p. 580; Hanna and others, p. 344); with three-grid valves (as loud-speaker valves, of high internal resistance, but avoiding the distortion caused by a two-grid valve worked in this way, owing to the secondary electrons reaching the screen whenever the plate voltage swings below the screen voltage); and with valves with oxide-coated filaments and indirectly-heated filaments. Regarding the last, the writer considers their chief interest to lie in the large diameter of the cathode, making low valve internal resistance possible (see above) and leading to a consequent decrease of distortion. He illustrates this by the diagram given below, in which the top curve is that given by an indirectly-heated valve, the next by a valve with oxide-coated filament, the lowest by a two-grid valve, while the peaked curve represents the old T.M. type valve.



Les Caractéristiques des Lampes de Réception Modernes et leur Choix rationnel (The Characteristics of Modern Receiving Valves, and their Selection for Various Purposes).—B. Decaux. (*L'Onde Élec.*, June, 1929, Vol. 8, pp. 262–281.)

Following on Jouaust's paper (see above) this article fills in certain gaps and gives details and values derived from various commercial types of modern valves. It also includes a bibliography of 28 items, English, American, French and German.

Ionic Processes and their Technical Application.—M. M. Sitnikoff. (*Trans. Phys. Tech. Lab.*, Moscow, 1929, No. 7, 103 pp.)

An investigation into the conduction of electricity by free ions and electrons in a gas. The present paper deals with the case where l (the electron free path) $>$ or $= b$ (distance between the electrodes). The various means of control (magnetic, volume or thermal) and applications (gas "convertor," rectifier, h-f and l-f oscillator) are discussed. Among the twelve points of the author's summary are the following:—the change of l is given as a function of the heating of a part volume of the gas; the length of trajectory between plane electrodes is expressed in terms of electric and magnetic fields; diagrams of the trajectory are plotted which serve to determine the conductivity of the zone of conduction, an approximation being also given for the trajectory in presence of a space charge. The theoretical results are confirmed by experiment. The phenomena of the mercury arc rectifier are examined. An approximate equality between electrical and thermal electron velocities corresponds to minimum losses in the arc: in this case $v_v + v_T = 1.4 \pm 0.15$ V. approx.

It is suggested that an important cause of ionisation by collision lies in the interaction between magnetic fields of moving electrons or ions (depending on their velocities) and the magnetic field of the system of electrons connected to a gas molecule. The phenomenon of the breakdown of thin solid dielectrics is considered, this being taken as a case where l is of the same order as b. The possible influence of a magnetic field on the breakdown is discussed (*cf.* Monkhouse, June Abstracts, p. 344). The paper is in Russian with an English summary.

Thermionic and Photoelectric Emission from Cæsium at Low Temperatures.—L. R. Koller. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1082.)

The Effect of Hydrogen on the Thermionic Emission from Potassium.—H. R. Laird. (*Phys. Review*, 1st Aug., 1929, Vol. 34, pp. 463–473.)

Fredenhagen's supposition that the thermionic currents frequently observed from potassium were due to hydrogen contamination is here confirmed by more rigorous test-methods. With the uniform fields of the writer's apparatus it was possible to saturate the thermionic currents observed from potassium at 150° to 185° C.; he suggests that the failure of Fredenhagen and of Richardson and Young to produce saturation was due to non-uniform field conditions. The hydrogen contamination appears to be in the form of a very thin coating of KH rather than of hydrogen physically absorbed; so that the emission seems due to decomposition of the KH rather than to true thermionic action.

Layers of Cæsium and Nitrogen on Tungsten.—N. A. de Bruyne. (*Proc. Cambridge Phil. Soc.*, July, 1929, Vol. 25, Part III, pp. 347–354.)

Investigation of the phenomenon of the appearance of two peaks on the filament-current/emission curve, before the setting in of the ordinary high temperature thermionic emission. The first peak is known to be the result of a cæsium layer on the tungsten; the second seems likely to be a combined effect of activated nitrogen and the cæsium, the nitrogen probably holding the cæsium atoms to the surface at a temperature above that at which a cæsium atom alone can stick.

Thermionic Emission through Double Layers.—W. Georgeson. (*Proc. Cambridge Phil. Soc.*, April, 1929, Vol. 25, Part II, pp. 175–185.)

Most of the calculations on the connection between χ and D (W) have been made, for simplicity, for the surface potential variation shown in Fig. 1. If, however, the surface layer behaves in any way like an ideal electrical double layer [Nordheim's explanation of the effect of surface layers in modifying the thermionic emission], the surface variation of potential energy will be much more nearly that shown in Fig. 2, and the writer has made calculations for this field, " which should represent the actual state of affairs quite closely."

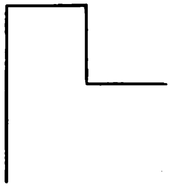


FIG. 1

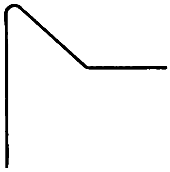


FIG. 2

General formulæ are obtained for the emission coefficients D (W), and graphs are drawn connecting the energies (W) of the electrons with D (W) for various thicknesses of layers, and for various values of the potential drops within them. It is shown that the emission coefficient does not vanish for $W = B$ as Nordheim states, but is of the order of $\frac{1}{2}$. The general Richardson formula for the thermionic current can be written $I = AT^2e^{-b/kT}$. It is shown theoretically that the presence of a layer on the metal, of thickness l, decreases the value of b by an amount equal to the drop of potential within the layer, while A depends upon l according to the relation $A = B\{l(\delta\chi)^{\frac{1}{2}}\}^{\frac{1}{2}}e^{-0.71l(\delta\chi)^{\frac{1}{2}}}$, where $\delta\chi$ is the potential drop in volts, and l is measured in units of 10^{-8} cm. With observed values of A and $\delta\chi$, this formula gives reasonable values for l. In the seemingly impossible case of a layer as thin as 10^{-8} cm. or thinner, A is practically unchanged from its value for a clean metal.

Note on " Oscillations in Ionized Gases."—L. Tonks and I. Langmuir. (*Phys. Review*, June, 1929, Vol. 33, p. 990.)

An explanatory note on the paper dealt with in May Abstracts, p. 273.

Thermionic Emission from Tungsten and the Schottky Equation.—H. Van Velzer and W. R. Ham. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1083.)

Values of the thermionic currents from tungsten filaments show that the Schottky relation can be verified with sufficient accuracy to furnish a satisfactory method of determining the electronic charge, e.

Thermionic Emission as a Function of the Amount of Adsorbed Material.—J. A. Becker. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1082.)

The Emission of Positive Ions from Tungsten at High Temperatures.—L. P. Smith. (*Phys. Review*, No. 2, 1929, Vol. 33, pp. 279–280.)

A summary of tests carried out after a short over-heating to 3,000° and a long run at 2,500° absolute. It is concluded that the positive ions are tungsten ions. The ion current remains unchanged, for a given temperature, by the introduction of an inert gas such as argon, provided that this is not dense enough to cool the filament appreciably.

Shot Effect of Secondary Electrons.—L. J. Hayner and A. W. Hull. (*Phys. Review*, No. 2, 1929, Vol. 33, p. 281.)

A summary of experiments on a number of valves. Among the various conclusions may be noted the deduction that the secondary emission occurs within 10^{-5} sec. after the impact of the primary electrons.

Über Ionenstrahlen (On Beams of Ions).—M. Zentgraf. (*Ann. der Phys.*, 15th July, 1929, Series 5, Vol. 2, No. 3, pp. 313–333.)

A repetition (with improved methods) and extension of G. C. Schmidt's researches in 1924. The salts covering the heated platinum wire included CdI_2, $PbCl_2$, thallium and silver salts. Among the results may be mentioned :—the beginning of emission depends on the pressure ; for low pressures the first ions emerge for smaller voltages than for higher pressures, but a small $+ve$ potential is always necessary to drive the ions out of the salts. Saturation occurs at very small voltages for small pressures, the voltage increasing with the pressure. In addition to the gradual decrease of the emission with time (which is part of an irreversible process) another variation with time can be found, due to deterioration and restoration of the surface. The deterioration is the more marked the higher the potential and the lower the temperature ; recovery sets in the quicker, the lower the potential and the higher the temperature.

The Distribution of Electrons between the Plate and Grid of a Three Electrode Tube as determined by Positive Cæsium Ions.—J. M. Hyatt. (*Phys. Review*, 1st Aug., 1929, Vol. 34, pp. 486–492.)

In a previous report (*ibid.*, Vol. 32, 1928, p. 922) experiments were described leading to the determination of the relative distribution of positive cæsium ions between the cylindrical plate and grid of a triode. The fraction of + ions caught by grid and plate respectively was proportional to the area of the solid and open portions of the grid. Since theoretically the paths of positive ions in such a valve are the same as those of electrons at the same accelerating voltage, it was assumed that with positive voltages of grid and plate the fraction of electrons caught by the plate would be measured by the ratio of the projected area on the plate of the open portion of the grid to the total plate area. The present paper deals with similar experiments on a plane-anode type of valve. Corresponding results were obtained.

UNE EXPLICATION POSSIBLE DE QUELQUES PHÉNOMÈNES DANS LE TUBE À RAYONS X (A Possible Explanation of Certain Phenomena in X-Ray Tubes).—A. Janitzky. (*Journ. de Phys. et le Rad.*, No. 1, 1929, Vol. 10, pp. 13S–14S.)

The writer concludes that gases are set free from metals in the form of positive ions: under the influence of high potentials they emerge from the anode, not the cathode, of a discharge tube. Since Hughes and Klein and others have shown that the ionising powers of very fast electrons are only small, he assumes that the above ionisation process must be carried out chiefly by positive ions. It must therefore be possible, by out-gassing the anode, to obtain such a condition that in spite of the presence of gas in the tube no discharge can take place, and also to work a hot cathode tube by purely electronic processes in spite of a comparatively high gas pressure. He has confirmed this by actual tests.

THE PRODUCTION OF EMISSION FROM OXIDE COATED FILAMENTS: A PROCESS PHENOMENON.—V. C. Macnabb. (*Journ. Opt. Soc. Am.*, July, 1929, Vol. 19, pp. 33–41.)

Author's abstract:—The production of oxide filaments of barium and strontium in an emitting condition is investigated from the standpoint of determining the advantages of several apparently different methods of producing this type of cathode as used by several different companies. It is found that all methods amount to the same thing and are different only in degree.

The fundamental underlying action of all methods is that the filament to become emissive must undergo a gaseous bombardment, which presumably causes a breaking down of the higher oxides or compounds, as the carbonate, to the lower oxides or pure metal, and conversely, this breaking down must be caused by or accompanied by a gaseous discharge in order to produce an active filament. The gas most suitable for this action is best obtained from the filament and is best produced from a carbonate that has not been reduced until put *in vacuo*; the gas then liberated and used is probably CO_2.

These conclusions are arrived at by experiments on several different types of filaments containing relatively different amounts of combined or baked-on coating to uncombined coating and in every case results favor those filaments containing most uncombined coating.

Some secondary conclusions are that the baked-on coating serves little or no purpose except as a mechanical bond and that the core material on which the coating can be placed may be of a wide variety of material.

PRODUCTION TESTING OF VACUUM TUBES.—A. B. Du Mont. (*Rad. Engineering*, June, 1929, Vol. 9, pp. 47–49.)

Description, by the De Forest chief engineer, of an automatic tester capable of handling 8,000 valves per hour, sorting out defective ones and ejecting them into different chutes according to their particular defects.

DIE GRUNDLEGENDEN VERFAHREN DER GLÜHLAMPEN-LEUCHTDRAHTTECHNIK (The Fundamental Processes of Incandescent Filament Technique).—B. Duschnitz. (*E.T.Z.*, 18th July, 1929, Vol. 50, pp. 1049–1053.)

(1) The Coolidge process: (2) The Pintsch process.

PENTONE VALVES. (*Journ. Scient. Instr.*, Aug., 1929, Vol. 6, p. 263.)

The characteristics of three types of Mullard "Pentones" are given.

SIMPLIFIED CONSTRUCTION OF MULTI-GRID VALVES. (Austrian Patent 109346, Müller and Halberstadt.)

To avoid the complications involved in the mounting of each grid separately, the inventors propose to construct one grid of wire composed of a bundle of two or more wires insulated from each other.

SPECIAL DESIGN OF ANODE FOR COOLING PURPOSES. (Austrian Patent 112794, Jacobi and Deszö.)

The sides of the anode parallel with the filament are so shaped as to give the anode a star-shaped polygonal section with projecting angles yielding good heat-radiation.

DIRECTIONAL WIRELESS.

LES APPLICATIONS DE LA RADIO-ÉLECTRICITÉ DANS LA NAVIGATION AÉRIENNE (The Applications of Radio-electricity in Aerial Navigation).—J. Marique. (*Bull. de la Soc. belge des Ing. et Ind.*, April-May and June, 1929, Vol. 9, Nos. 3 and 4, pp. 235–261 and 371–384.)

A general survey. A final section deals with the organisation in Belgium. There is a short section on blind landing; for height above the ground, a patent by Leroy is mentioned, to make use of the increasing effect of the ground on the tuning of a very h-f oscillating circuit (French Patent 952075), while it is stated that Jenkins has proposed a system based on the reflection of very short waves (Papin, "Le Radioaltimètre," *T.S.F. Moderne*, 1926). Alexanderson's experiments are not mentioned. For picking up the landing ground, Loth's leader-cable system is mentioned, and Willoughley's [?] proposal of a system of horizontal frames one above the other to produce a reversed-cone-shaped upwards beam. The angle corresponding to maximum intensity is about 30 degrees on either side of the vertical, for a system of two frames: it can be reduced by increasing the number (Breit, *Scient. Papers B. of Stds.*, No. 413). "An analogous radiation diagram would be obtained with a vertical aerial vibrating to a harmonic." The Bureau of Standards' use of a small vertical aerial on the aeroplane, so that signals vanish suddenly when the machine is above the station, is also mentioned: "tests have shown that the beacon can be located within 30 metres by an aeroplane flying at 300 metres' height."

A Course-Shift Indicator for the Double-Modulation Type Radiobeacon.—H. Diamond and F. W. Dunmore. (*Bur. of Stds. Journ. of Res.*, July, 1929, Vol. 3, pp. 1–10.)

To increase the reliability of the visual directive radiobeacon system, this indicator has been developed—primarily for station use—to indicate to a station operator whether a given course as laid out in space remains unchanged, and to facilitate a check of the beacon calibration. The apparatus consists essentially of an electrostatically shielded rotatable pick-up coil coupled magnetically to both loop aerials of the beacon and connected to a detector-amplifier unit. The output of this, containing both the beacon frequencies, branches through suitable filters to the two sets of windings of the indicating instrument, which is a modified form of a commercial frequency meter. The two windings are in opposition, so that when the course is set and the two filters properly adjusted, the instrument pointer assumes a mid-scale (zero) position. Any deviation from this indicates that the course is varying—a change of 0.1 degree being readily detected.

The use of the apparatus for easy re-calibration of the beacon is obvious. Another use still is as a visual course indicator, on aircraft large enough to put up with its extra weight, instead of the usual two-reed indicator. It has the advantage of giving extremely sharp indication of course, but it is less robust and more liable to interference than the reed instrument.

ACOUSTICS AND AUDIO-FREQUENCIES.

On the Acoustics of Large Rooms.—M. J. O. Strutt. (*Phil. Mag.*, Aug., 1929, Vol. 8, No. 49, pp. 236–250.)

Author's abstract:—The theoretical proofs hitherto given in literature of Sabine's experimental result, that the duration of residual sound in a large room does not depend upon the shape but only on the volume and the absorbing power, and is the same (generally) if measured in different points with the source at different places, may be said to be incomplete. They start from considerations of reflection at the walls, but phase relations are left out. Moreover, often a homogeneous distribution of sound-energy over space at the moment the source stops is assumed, which will not be true in various cases that, on the other hand, experimentally check Sabine's law very well. The present treatment discusses the problem of forced oscillations in a continuous medium with arbitrarily distributed absorption, and shows Sabine's law to be a general asymptotic property of such oscillations, if the quotient of the forced frequency over the lowest free frequency of the system tends to infinity. In addition, various special experimental features are discussed from this point of view. The prevalence of Sabine's law in other departments of physics, e.g., with the electromagnetic radiation in closed spaces, is predicted from its general character.

Conditions of Securing Ideal Acoustics in Auditoriums.—F. R. Watson. (*Phys. Review*, No. 2, 1929, Vol. 33, p. 283.)

Messung der Gesamptenergie von Schallquellen (Measurement of the Total Energy of Sound Producers).—E. Meyer and P. Just. (*Zeitschr. f. tech. Phys.*, Aug., 1929, Vol. 10, No. 8, pp. 309–316.)

Just as Ulbricht's sphere-photometer gives the integral value of the total light emission of a lamp without multiple measurements in various directions, so the writers devised a method for determining the total emission of a sound-producer. The measurement took place in a completely closed rectangular room of dimensions at least comparable with the longest wavelengths, and with as little absorption as possible. The absorption was measured by the objective method due to the writers (Sept. Abstracts, p. 513, and 1928, p. 649). The pressure-amplitudes were measured by a microphone calibrated electrostatically, a Reiss carbon microphone as well as a condenser microphone being used at different times. From the absorption and pressure-amplitude data thus obtained, the total output was calculated by the Jäger theory. The correctness of the method was tested by numerous preliminary experiments, and as examples of its usefulness various frequency curves and efficiency measurements of loud-speakers are given, and also some energy-measurements of human speech and of certain musical instruments.

Speech-power of Speakers in Auditoriums.—V. O. Knudsen. (*Phys. Review*, 1st August, 1929, Vol. 34, p. 549.)

Abstract only. Measurements indicate that the loudness of speech in auditoriums is considerably below the loudness level required for best hearing conditions. The probable loudness of the average speaker is 50.7 db and 45.7 db for a small and a large auditorium respectively: optimum loudness for the hearing of speech is 70 db. These and other data lead to the possibility of arriving at a quantitative rating of the hearing conditions in any auditorium.

Beiträge zur Raumakustik (Contributions to our Knowledge of the Acoustics of Rooms).—W. Schindelin: E. Scharstein: E. Scharstein and W. Schindelin. (*Ann. der Phys.*, 28th June, 1929, Series 5, Vol. 2, No. 2, pp. 129–162, 163–193, 194–200.)

A.E.G. Coil-driven Loud Speaker (Rice-Kellogg).—F. A. Fischer and H. Lichte. (*A.E.G. Mitt.*, Jan., 1929, No. 1, pp. 25–31.)

The loud speaker is described, and it is shown mathematically that below frequencies corresponding to wavelengths of the same order of magnitude as the diaphragm-diameter, the efficiency of conversion is independent of frequency, while above this critical zone the efficiency is proportional to the square of the wavelength.

In Search of Quality: the Construction and Performance of a 25 ft. Logarithmic Horn.—R. P. G. Denman. (*Wireless World*, 31st July, 1929, Vol. 25, pp. 97–101.)

The mouth of this horn was formed by an octagonal room whose ceiling sloped down to the walls

from a central horizontal portion: this horizontal portion was removed and the horn built above the gap thus left.

TRANSMISSION OF SOUND THROUGH WALL AND FLOOR STRUCTURES.—V. L. Chrisler and W. F. Snyder. (*Bur. of Stds. Journ. of Res.*, March, 1929, Vol. 2, pp. 541–559.)

ÜBER DIE EXPERIMENTELLE BESTIMMUNG DES WIRKUNGSGRADES EINES BANDLAUTSPRECHERS (The Experimental Determination of the Efficiency of a Band Loud-speaker).—H. Graf. (*Zeitschr. f. tech. Phys.*, Aug., 1929, Vol. 10, No. 8, pp. 334–339.)

The writer employs a method analogous to that used by Barkhausen and others to measure the efficiency of submarine acoustic transmitters; but in his case the measurements of the ohmic resistance and the in-phase and wattless components of the band reactance are taken first in air and then in a vacuum, and instead of a wattmeter a Wheatstone bridge is used. As, however, the method is only applicable to an apparatus giving a fairly well-marked resonance curve (since it depends on a comparison between the decrements in air and *in vacuo*), a special band with a marked resonance point was substituted for the usual loud-speaker band. [It would thus seem that the title of the paper is somewhat misleading, since the apparatus tested was a note-generator rather than a loud-speaker.] Curves of results are given: a Vogt aluminium alloy proved the best material for the purpose.

THE KYLE CONDENSER LOUD SPEAKER.—V. F. Greaves, F. W. Kranz, and W. D. Crozier. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1142–1152.)

This paper presents some of the theoretical considerations involved in the design of the Kyle loud-speaker (see Sept. Abstracts, p. 514) together with a brief discussion of the practical problems met with in its design and application.

THE INDUCTOR DYNAMIC (FARRAND LOUD-SPEAKER MOVEMENT).—H. P. Westman. (*QST*, Aug., 1929, Vol. 13, pp. 29–30.)

A design is described and illustrated which is of the magnetic type but has the same kind of armature motion as a moving coil; the armature is allowed to "float" within the gap between opposing pole-pieces and yet moves parallel to these so that its motion does not alter the length of the gaps. Restoration is due entirely to the magnetic field caused by the permanent magnet.

MOUNTING THE GRAMOPHONE PICK-UP.—(*Wireless World*, 7th Aug., 1929, Vol. 25, pp. 132–133.)

"If an ordinary tone arm is correctly placed and the pick-up is properly adjusted thereon, the tracking can be made to approach very nearly to the ideal [a maximum departure from tangential tracking of below 2° is mentioned later] without the inclusion of special devices for ensuring a straight line motion or its equivalent..... The track of the needle should not pass through the centre of the turntable." A simple formula for calculating the best position, for a tone arm of any length, is given.

TRANSIENTS IN LOUD SPEAKERS AND AMPLIFIERS: HOW SUDDEN CHANGES IN SOUND INTENSITY AFFECT THE AMPLIFIER: THE IMPORTANT EFFECT OF A CHOKE-FILTER OUTPUT.—N. W. McLachlan. (*Wireless World*, 7th and 14th Aug., 1929, Vol. 25, pp. 118–121 and 154–157.)

VERSTAANBAARHEID VAN LUIDSPREKERINSTALLATIES (The Intelligibility of a Loud Speaker). C. Zwikker. (*De Ingenieur*, S. Africa, No. 13, 1929; a rather full German Abstract of this paper is to be found in *Physik. Berichte*, 1st Aug., 1929, Vol. 10, No. 15, pp. 1537–1538.)

APPLICATION OF MICROPHOTOMETERS FOR THE ANALYSIS OF PHOTOGRAPHIC SOUND RECORDS.—J. T. Tykociner. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1094.)

FREQUENZKURVEN VON ELEKTRISCHEN TONABNEHMERN UND MECHANISCHEN GRAMMOPHONEN (Frequency Curves of Electric Pick-Ups and Mechanical Gramophones).—E. Meyer and P. Just. (*E.N.T.*, July, 1929, Vol. 6, pp. 264—268.)

In order to make use of gramophone test-records giving pure notes varying from 6,000 to 100 p.p.s., or "howling" notes of a breadth of 100 p.p.s. whose mid-point varies from 150 to 6,000 p.p.s., the writers have devised a simple way of measuring the amplitudes communicated to the needle at different points on the record. An electrical pick-up is employed, and the speed of rotation is adjusted so that the different parts of the record, tested in turn, give—not their own special note—but a fixed deep note. The amplitude at each part is then measured by the voltage at the pick-up output terminals. In actual practice it is found best to cover the whole range of the record in two or more overlapping stages. The records, calibrated by this method, can then be used for plotting frequency curves, various examples of which are given.

STUDY ON THE CHARACTERISTICS OF ACOUSTIC TUBES.—K. Kobayasi. (*Tech. Rep. Tôhoku Univ.*, Sendai, 1929, Vol. 8, No. 3, pp. 65–119.)

In English. Part I. deals with acoustic wave filters (*a*) low-pass and band-pass, and (*b*) high-pass. The transmission characteristics of systems consisting of short tubes of various cross sections variously arranged are investigated by means of hyperbolic parameters, and the equivalent electrical circuits for class (*a*) are discussed. Procedure for the design of filters of both classes is outlined. Part II. deals with an investigation of the propagation of sound in hair-felt and such absorbent materials, a direct method of measuring extremely small acoustic impedances being described which enables such an investigation to be carried out. Part III. deals with the characteristics of a rubber

tube. A working theory of the rubber tube as an acoustic tube having a non-rigid wall is formulated, and confirmed practically exactly by tests using the above-mentioned method, and by other tests using the vibrometer method. It was thus found that the latter method, when combined with "an ideal acoustic transformer of high ratio and high primary stiffness" can also be used satisfactorily for measuring small acoustic impedances. A bibliography of 38 items ends the paper.

EXPERIMENTAL AND THEORETICAL MID-SERIES CHARACTERISTIC IMPEDANCE OF ACOUSTIC WAVE FILTERS.—G. W. Stewart and C. W. Sharp. (*Journ. Opt. Soc. Am.*, July, 1929, Vol. 19, pp. 17–28.)

A comparison between the simplified Stewart theory of these tube filters and the less approximate theory of Mason, made by checking the two theories against experimental results with high-pass, low-pass and single-band-pass filters. For ascertaining cut-offs, and the characteristic impedance of low-pass filters, the Stewart theory is more readily applicable and appears satisfactory.

EXPERIMENTAL ANALYSIS OF THE FORCE EXERTED BY SOUND WAVES ON AN AIR RESONATOR.—E. Waetzmann and K. Schuster. (*Ann. der Phys.*, 25th Feb., 1929, Vol. 1, No. 4, pp. 556–564.)

The three components are :—an attractive force independent of frequency ; a phase force, attractive below resonance and repulsive above ; a resonance force, repulsive for all frequencies and a maximum for the resonant frequency. Maximum attraction is separated from maximum repulsion by a very small range of frequency.

IMPROVED REPRODUCTION BY THE REDUCTION OF DISTORTION DUE TO ANODE RECTIFICATION.—A. G. Warren. (*See* under "Properties of Circuits.")

PHOTOTELEGRAPHY AND TELEVISION.

COLOUR TELEVISION. (*Nature*, 10th Aug., 1929, Vol. 124, p. 241.)

A paragraph dealing with the report of a demonstration of colour television by Ives. 3 groups of photoelectric cells are used, each covered with a primary colour filter ; while at the receiver, the signal operates glow-lamps behind coloured screens.

RESEARCHES IN CATHODE RAY TUBE TELEVISION. L. B. Rosing. (*T.i T.b.p.*, No. 2, 1929, Vol. 10, pp. 185–194.)

In Russian.

LE PROBLÈME DE LA TÉLÉVISION (The problem of Television).—B. Decaux. (*T.S.F. Moderne*, Feb., 1929, Vol. 10, pp. 63–76.)

The writer defines the problem, explains its difficulties and describes the present attempts to solve them—which he considers to be only provisional. He ends by giving his opinion that television is now in the position of radio-telephony before the introduction of valves, and that no progress can be hoped for except from new methods—possibly connected with cathode rays and phenomena such as the Kerr effect.

PIEZOELECTRIC AIR CURRENTS USED FOR RELAY PURPOSES.—(German Patent 475374, Telefunken, published 24th April, 1929.)

The air currents produced by an oscillating piezoelectric crystal are used to deflect a mirror (for picture telegraphy) or a liquid jet, or to close a contact.

REFLEXIONSABTASTUNG BEI BILDTELEGRAPHEN (Reflection Scanning for Picture Telegraphy).—F. Schröter. (*Zeitschr. f. tech. Phys.*, Aug., 1929, Vol. 10, No. 8, pp. 323–327.)

The use of a paraboloid reflector to collect the rays diffused from the scanned picture is dealt with in February Abstracts, p. 108. The present paper gives a detailed account of the latest developments of this method, as used in the S.K.T. system. The paraboloid mirror is replaced by an ellipsoidal mirror, which gives better results.

SEPARATION OF PICTURE SIGNAL FROM SYNCHRONISING SIGNAL. (German Patent 475831, Lorenz, pub. 11th May, 1929.)

Difficulty in separating the modulation frequency representing the picture signals from the synchronising signal frequency is here avoided by suppressing one sideband of each, on opposite sides of the carrier frequency : the remaining modulated frequencies, being one on each side of the carrier, can readily be separated.

FIXING "FULTOGRAPH" PICTURES.—A. J. H. Iles. (*Electrician*, 23rd August, 1929, Vol. 103, p. 234.)

The permanent fixing of pictures on starch and potassium iodide sensitised paper is here stated to be possible by treatment with alum (one tea-spoonful to a pint of water).

THE MAGNETO-OPTICAL DISPERSION OF SOME ORGANIC LIQUIDS IN THE ULTRA-VIOLET REGION OF THE SPECTRUM.—C. C. Evans and E. J. Evans. (*Phil. Mag.*, August, 1929, Vol. 8, No. 49, pp. 137–158.)

The magneto-optical rotations of two alcohols and of methyl and ethyl acetate are investigated for various wavelengths in the violet and near ultra-violet regions, and equations obtained representing the magneto-rotary dispersions.

MICROSCOPIC STUDY OF ELECTRIC DOUBLE REFRACTION IN LIQUIDS.—M. Iwatake. (*Tech. Rep. Tôhoku Univ.*, Sendai, 1929, Vol. 8, No. 3, pp. 121–132 and 7 plates.)

In English. The Kerr effect is usually supposed to appear uniformly in the space between the plates of the condenser, but the writer has found certain complications of the phenomenon during his photo-micrographic study of the effect under a high continuous potential of several thousand volts : the effect, in nitrobenzene, nitrotoluol-ortho and pyridin (but apparently not in carbon

disulphide), does *not* appear uniformly in the space if it is between parallel plates, and less still if the electrodes are cylindrical. Results suggest that the field in the gap is not uniform, perhaps because of the stratified settling of an inhomogeneous liquid. A bibliography of 49 items is included in the paper.

Relation between Blackening of Photofilm and Potential Difference on Kerr Condenser in Picture Transmission Systems using Photoelectric Cells.—P. V. Shmakov. (*T.i T.b.p.*, No. 2, 1929, Vol. 10, pp. 147–152.)

In Russian.

No Time-Lag in Kerr Effect.—E. Gaviola. (*See* under "General Physical Articles.")

Light-Sensitive Cells.—J. P. Arnold. (*Rad. Engineering*, March, April, May and June, 1929, Vol. 9.)

(1) Construction of Alkali Metal Cells; Nature and Treatment of the Light-sensitive Material; (2) Characteristics of the Alkali Metal Cell; (3) Amplification, Measurement and Utilisation of Photoelectric Currents; (4) Practical Cells of Various Types.

Effects of a Crystallographic Transformation on the Photoelectric and Thermionic Emission from Cobalt.—A. B. Cardwell. (*Proc. Nat. Acad. Sci.*, July, 1929, Vol. 15, pp. 544–551.)

The Use of Dielectrics to Sensitize Alkali Metal Photoelectric Cells to Red and Infra-Red Light.—A. R. Olpin. (*Phys. Review*, June, 1929, Vol. 33, p. 1081.)

A technique is described for increasing greatly the response (especially in the red) of sodium and potassium surfaces in a vacuum by the introduction of very small amounts of such dielectrics as sulphur vapour, water vapour, benzene, and organic dyes. A theory is proposed which suggests a modulation of the exciting light at the cathode surface, the incident frequency combining with the characteristic vibration frequency of the dielectric. See also the same author, *ibid.*, 1st Aug., 1929, p. 544. Experimental data confirm the various theoretical conclusions arrived at.

The Photoelectric and Thermionic Properties of Molybdenum.—M. J. Martin. (*Phys. Review*, June, 1929, Vol. 33, pp. 991–997.)

Untersuchungen über den selektiven Lichtelektrischen Effekt an dünnen, auf einem Platinspiegel adsorbierten Kaliumhäuten (Investigations into the Selective Photoelectric Effect in Thin Potassium Films adsorbed on a Platinum Mirror).—R. Suhrmann and H. Theissing. (*Zeitschr. f. Phys.*, 5th July, 1929, Vol. 55, No. 11/12, pp. 701–716.)

Various thicknesses of film were used, from monatomic thickness upwards. A monatomic film gave a normal sensitivity curve with normal ratio. A slightly thicker film gave a high spectral maximum with a strongly selective ratio, at 340 mμ. With still thicker films the maximum moved towards the longer wavelengths and became distinctly smaller.

The Preparation of Photoelectric Cells with Thin Films of Lithium as the Photoactive Material.—H. E. Ives. (Summary in *Phys. Review*, June, 1929, Vol. 33, pp. 1081.)

Thermionic and Photoelectric Emission from Cæsium at Low Temperatures.—L. R. Koller. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1082.)

Talbot's Law in Connexion with Photo-electric Cells.—G. H. Carruthers. (*Phil. Mag.*, August, 1929, Vol. 8, No. 49, pp. 210–213.)

In connection with the difference of opinions referred to in September Abstracts, the writer describes some tests which confirm that the fatigue effect in question does not occur to any appreciable extent in any single exposure of a cell by a rotating sector, but takes place over a number of such exposures corresponding to a period of exposure of ½ to 5 secs. The cell used was a cæsium one exhibiting distinct non-proportionality.

Photoelektrischer Effekt von dielektrischen Oberfläche nach vorhergehender Aufladung durch langsame Elektronen (Photoelectric Effect of Dielectric Surfaces after a Preliminary Charging by Slow Electrons).—P. S. Tartakowsky (*Journ. Russ. Phys. Chem. Ges.*, 1927; long summary in *Physik. Berichte*, 15th June, 1929, Vol. 10, No. 12, pp. 1182–1183.)

Measurement of the Photoelectric Effect during Change of State of Kathode.—A. Goetz. (*Zeitschr. f. Phys.*, Feb., 1929, No. 7/8, Vol. 53, pp. 494–525.)

Temperature range was from 50° to 550°. Among the results found was the conclusion that the photoelectric emission is independent of temperature so long as there is no change of state or allotropic form.

Experiments on the Photoelectric Effect in Thin Films of Potassium and Sodium.—W. F. G. Swann: Nottingham. (*Journ. Franklin Inst.*, Aug., 1929, Vol. 208, pp. 235–244.)

MEASUREMENTS AND STANDARDS.

Sur les Vibrations suivant l'Axe optique dans un Quartz piézo-électrique oscillant (On the Vibrations following the Optical Axis in an Oscillating Piezoelectric Quartz Crystal).—E. P. Tawil. (*Comptes Rendus*, 22nd July, 1929, Vol. 189, pp. 163–164.)

According to Curie's laws there should be no piezoelectric deformation along the optical axis: recent work on oscillating quartz has shown the

existence of a fundamental frequency which seems to correspond to a mode of vibration along that axis, but there has been hesitation in accepting results which would contradict the theory, and various authors have proposed explanations based on no experimental facts. The writer's tests by his method using polarised light and by the use of ultra-audible waves convince him that undoubtedly such vibrations do take place.

On the Modes of Vibration of Quartz Crystal.—J. W. Harding and F. W. G. White. (*Phil. Mag.*, August, 1929, Vol. 8, No. 49, pp. 169–179.)

"The existence of nodes and antinodes on the surface of an oscillating quartz crystal has been demonstrated by A. Crossley [Abstracts, 1928, Vol. 5, p. 349] using ferro-ferricyanide solution as an indicator. It is stated that lycopodium powder was tried but was thrown off, leaving no trace on the crystal. Using a fairly thick crystal [4 × 3.5 × 2.5 cms.] the present writers have found lycopodium powder very effective, and a comprehensive study of the various patterns formed on the crystal surface for various modes of vibration has been carried out. Special care has been taken to trace the connection between the modes of vibration of the faces and the air-currents which may issue from those faces."

Observations on Modes of Vibration and Temperature Coefficients of Quartz Crystal Plates.—F. R. Lack. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1123-1141.) *See* Sept. Abstracts, p. 518.

Piezoelectric Effect of Diamond.—W. A. Wooster. (*Min. Mag.*, March, 1929, Vol. 22, pp. 65–69.)

No effect could be detected: in any case it must be less than 1/200th of that of quartz.

The Piezoelectrical Properties of Amorphous and Crystalline Substances in an Electric Field.—A. Subnikov and B. Brunovskij. (*Bull. Ac. Sc. Leningrad*, No. 4/5, 1928, pp. 367–374.)

Every dielectric whose particles (molecules or other structural elements) are subjected to displacements in an electric field are piezoelectric to a greater or less extent. If the particles are set into vibration by a mechanical shock, periodic compression and extension effects are produced which result in a supplementary field whose direction alternates in time with these vibrations: thus the external field is alternately increased and diminished. 84 minerals were examined; cinnabar gave the most marked, asbestos and barytes the least effect. Of artificial materials, impregnated wood gave the greatest result, and glass the least.

Untersuchung über Pyro- und Piezoelektrizität (An Investigation into Pyro- and Piezoelectricity).—A. Meissner. (*Naturwiss.*, 11th Jan., 1929, Vol. 17, pp. 25–31.)

Part of this paper was dealt with in September Abstracts. It includes also an explanation of pyro- and piezoelectric phenomena on the assumption that the smallest structural element in quartz possesses the same properties, in these ways, as a large crystal. It deals also with the pyroelectric moment of quartz after heating to various temperatures and subsequent cooling; the moment is found to be proportional to the temperature, and is upset by a crystal-conductivity which is dependent on the temperature. The writer goes on to refer to the artificial piezoelectric substances dealt with in March Abstracts, p. 159: no new progress of importance seems to have been made here.

Growing Crystals for Piezoelectric Elements. (German Patent 475567, Int. Gen. Elec. Co., published 30th April, 1929.)

A seed crystal is cut from the parent crystal so that one of its faces is parallel to a certain face of the complete crystal. The seed crystal is placed between two plates spaced the thickness of the required crystal, the special face lying against one plate. The whole is immersed in a mother liquor to grow till the required thickness is reached.

Measurement of Wavelengths of Broadcasting Stations.—R. Braillard and E. Divoire. (*See* under "Stations, Design and Operation.")

The Routine Measurement of the Operating Frequencies of Broadcast Stations.—H. L. Bogardus and C. T. Manning. (*See* under "Stations, Design and Operation.")

Note on the Ratio of the Electromagnetic to the Electrostatic Unit of Electricity as compared to the Velocity of Light.—H. L. Curtis. (*Bur. of Stds. Journ. of Res.*, July, 1929, Vol. 3, pp. 63–64.)

Gruneisen and Giebe in 1920 announced a determination of the absolute measurement of the international ohm which differed by only 1 part in 100,000 from the value found in 1913 by F. E. Smith. Recent tests at the Washington Bureau show that this value is not in error by as much as 1 part in 10,000. The best value to date for the ratio of electromagnetic to electrostatic unit is therefore 299,790 km./sec. Michelson's recent value of the velocity of light is 299,796 ± 4 km./sec., and a preliminary determination by Karolus and Mittelstaedt (*see* under "Prop. of Waves") gives 299,778 ± 20 km./sec. Thus the ratio of units agrees with the measured velocity within the limits of present measurement.

A Comparison of the Formulas for the Calculation of the Inductance of Coils and Spirals wound with Wire of Large Cross Section.—F. W. Grover. (*Bur. of Stds. Journ. of Res.*, July, 1929, Vol. 3, pp. 163–190.)

Author's summary:—Two methods have been used for the calculation of the inductance of coils of wire having a relatively large cross section. Of these, the summation method gives the inductance of the coil as the sum of the self-inductances of the turns and the mutual inductances of all the pairs of

turns. The Rosa method calculates the inductance of the equivalent current sheet as a first approximation to the inductance of the coil, and obtains the correction which must be applied by calculating (*a*) the differences between the self-inductance of the turns of wire and of the current sheet and (*b*) the differences of the mutual inductances of pairs of turns of wire and of the corresponding turns of the current sheet.

It is here shown that, contrary to previous opinions, the two methods give identical results, when terms of the same degree are retained in the series expressions.

The accurate formula of Snow for the inductance of a helix is written so as to include the Rosa correction terms, and it is proved that the error of the Rosa method may be neglected in all except the most precise work.

It is recommended that, lacking precision formulas, the Rosa method be used as giving a general solution of the problem in such cases where the current sheet formula is known. Certain important cases are reviewed briefly.

Resistance of Air Condensers.—R. R. Ramsey and B. D. Morris. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1076.)

Studio del Triodo come Amplificatore Balistico per la Misura di Piccole Capacità (Study of the Three-Electrode Valve as a Ballistic Amplifier for the Measurement of Small Capacities).—E. Cristofaro and G. Sacerdote. (*Elettrotec.*, 25th July, 1929, Vol. 16, pp. 494–498.)

The method consists essentially in charging the capacity to be measured to a known voltage and then discharging it through a resistance, one end of which is connected to the grid of a triode. Thus this grid (in whose circuit no current was flowing previously) is suddenly subjected to a change of potential. A ballistic galvanometer in the anode circuit integrates the corresponding change of anode current over the time of the discharge and thus gives a measure of the charge of the capacity.

Electrical Wave Analyzers for Power and Telephone Systems.—R. G. McCurdy and P. W. Blye. (*Journ. Am.I.E.E.*, June, 1929, Vol. 48, pp. 461–464.)

The telephone circuit analyser operates over a frequency range from 75–3,000 cycles and measures harmonic currents down to 0.05 microampere and voltages as small as 0.005 millivolt. It employs multi-stage valve amplifiers and two duplicate inter-stage selective circuits. Special devices for suppressing the fundamental component and for balancing out harmonics generated in the input transformers are provided.

Ein neuer Ohmscher Spannungsteiler für Hochfrequenz (A New Ohmic Potential Divider for H.F.).—M. v. Ardenne. (*Elektrot. u. Masch : bau*, 2nd June, 1929, Vol. 47, pp. 471–472.)

A discussion of the desirability of ohmic potential dividers in the test room, instead of those of capacitive type or inductive couplings, leads to the remark that the first have scarcely been used in the past because of the lack of non-inductive and capacity-free resistances. The use of Loewe resistances, which with associated leads have a capacity of only 2 cms., is recommended.

Gekreuzte Zylinder als Funkenstrecke (Crossed Cylinders as Spark Gap).—E. Werner. (*Arch. f. Elektrot.*, 8th May, 1929, Vol. 22, No. 1, pp. 1–19.)

For high voltage measurements, crossed cylinders (suggested by Schwaiger) are shown to be superior to all other forms of spark gap hitherto used.

Shielding in High-Frequency Measurements.—J. G. Ferguson. (*Bell Tech. Journ.*, July, 1929, Vol. 8, pp. 560–575.)

Mesure des Valeurs maxima instantanées des Tensions à brusques Variations (Measurement of Instantaneous Maximum Values of Suddenly Varying Tensions).—H. André. (*Rev. Gén. de l'Élec.*, 29th June, 1929, Vol. 25, pp. 1013–1015.)

A paper on the use of a thermionic peak voltmeter comprising a triode, a condenser and a potentiometer.

SUBSIDIARY APPARATUS AND MATERIALS.

Die Drehzahlregelung von Gleichstrommotoren mit Elektronenröhren (The Speed Regulation of D.C. Motors by Thermionic Valves).—E. Reimann. (*Wiss. Veröff. Siemens Konz.*, vi/2, 1928.)

A theoretical investigation of the method dealt with in February Abstracts, p. 111. For a summary, *see* E.u.M:bau, 14th July, 1929.

An Improved Constant Current Regulator.—L. G. Longsworth and D. A. MacInnes. (*Journ. Opt. Soc. Am.*, July, 1929, Vol. 19, pp. 50–55.)

An arrangement involving a small continuously running motor driving a disc against which either of two clutch-discs can be pressed, one of which by its rotation increases the current while the other decreases it. By a galvanometer with a reflecting vane on its indicator, and a photoelectric cell with relay, the two opposing clutch-discs are kept so working that the galvanometer remains "hovering" about its zero point—which corresponds with the constant current required. For circuits subjected to small variations of resistance and E.M.F., the resulting constancy is within 0.01 per cent.

Nouveau Régulateur automatique de Tension (A New Automatic Voltage Regulator).—P. Toulon. (*Rev. Gén. de l'Élec.*, 3rd Aug., 1929, Vol. 26, pp. 189–191.)

A regulator based on the different current/voltage curves of a simple ohmic resistance and of a neon tube, and therefore similar to the regulator dealt with by Roder in Germany (September Abstracts, p. 522) who used an ordinary metal filament lamp but who mentioned the equal suitability of neon

tubes. The present writer gives 0.2 per cent. as the approximate variation of voltage for a 10 per cent. variation of supply voltage. 20 neon lamps are used for an output power of 120 w. A practical portable form of the regulator is illustrated.

AUTOMATIC VOLTAGE REGULATOR FOR DIRECT CURRENT.—G. T. Winch and A. Bone. (*Journ. Scient. Instr.*, Aug., 1929, Vol. 6, pp. 247–249.)

An arrangement involving a constant voltage potentiometer in opposition to the fluctuating voltage, relays, and a small motor operating—through reduction gearing—a mercury resistance. It maintains a constancy of within $\pm \frac{1}{2}$ per cent.

A BATTERY REVOLUTION: THE DRUMM ACCUMULATOR.—(*Electrician*, 30th Aug., 1929, Vol. 103, p. 239.)

A paragraph on the reports from Ireland of this new accumulator, which, it is said, can be fully charged in a few minutes and which is to be used to electrify the main railway line between Dublin and Cork.

SPEED INDICATOR AND FREQUENCY METER.—E. H. Greibach. (*Journ. Am.I.E.E.*, August, 1929, Vol. 48, pp. 633–634.)

This simple mechanical speed indicator, which when driven positively by a synchronous motor can serve as an accurate frequency meter, consists of a transparent cup rotating about a vertical axis and containing one or more balls. The ball climbs along the inside wall until it is in equilibrium, when the centrifugal force and gravity give a resultant perpendicular to the tangent to the inside surface. With a cup designed to give precise indication through a range of $\pm$ 2 per cent. of a given speed, the order of precision is about one-tenth of 1 per cent. Much wider ranges of variation can be designed for.

A NEW TYPE OF HOT CATHODE OSCILLOGRAPH.—R. H. George. (*Journ. Am.I.E.E.*, July, 1929, Vol. 48, pp. 534–538.)

The paper describes a general purpose type, capable of operating at any potential from 500 to 20,000 volts or more, and a special portable type. Among special features are the following:—a "hot cathode electron gun" which makes possible automatic starting and stopping of the beam (e.g. by a lightning surge, within $\frac{1}{2}$ to $\frac{1}{4}$ microsecond after the surge voltage begins to rise from zero); a new electrostatic method of focusing the beam; the entire beam passes through the high-voltage anode, thus eliminating the problem of anode heating.

THE EFFECT OF GASES ON THE RESISTANCE OF GRANULAR CARBON CONTACTS.—P. S. Olmstead: (*Journ. Phys. Chem.*, No. 1, 1929, Vol. 33, pp. 69–80.)

Contact-resistance changes under variations of applied voltage and of surrounding gas pressure are explained on the assumption that the gas forms surface layers which take some of the total contact pressure and thus increase the resistance. The pores of the carbon absorb gas which, on the reduction of pressure in the surrounding gas, emerge and penetrate into the contact-points.

REMOVAL OF FILMS AND PLATES FROM C-R OSCILLOGRAPHS WITHOUT DISTURBING THE VACUUM.—P. Hochhäusler. (*E.T.Z.*, 8th Aug., 1929, Vol. 50, pp. 1175–1176.)

Discussion on the paper dealt with in September Abstracts, p. 520.

"PYREX" GLASS AS A DIELECTRIC.—C. L. Dawes and P. H. Humphries. (*Elec. World*, Vol. 91, p. 1331.)

NOTE ON HIGH VOLTAGE LEYDEN JARS.—P. P. Quayle. (*Journ. Opt. Soc. Am.*, May, 1929, Vol. 18, pp. 407–410.)

A jar of Pyrex glass is described. Many ordinary jars will break down if occasionally subjected to potentials of the order of 10^5 volts for a period of 4 to 6 months; but the pyrex jars have given no trouble during 14 months of use. They are said to be quite inexpensive.

HOCHLEISTUNGSSCHALTER OHNE ÖL (High-power Switches without Oil).—J. Biermanns. (*E.T.Z.*, 25th July, 1929, Vol. 50, pp. 1073–1079.)

First part of an article on the A.E.G. compressed air switch, capable of controlling up to 500,000 kVA.

DIE NEUE ENTWICKLUNG DES GLIMMERKONDENSATORS (The New Development of the Mica Condenser).—F. Gerth and H. Gönningen. (*E.T.Z.*, 8th August, 1929, Vol. 50, pp. 1156–1159.)

Authors' summary:—After a short historical survey, the recent development of the mica condenser, particularly for use with high frequencies, is described. It is shown that with good mica the possible H.F. load is controlled not by the dielectric strength but by the appearance of brush discharge and by the heating caused by dielectric loss. A number of recent designs, based on the latest knowledge, are described and illustrated.

UNTERSUCHUNGEN ÜBER DEN DURCHSCHLAG UND DIE VERLUSTE EINIGER FESTER ISOLIERSTOFFE (Investigations into the Breakdown and Losses of Some Solid Insulating Materials).—K. Halbach. (*Arch. f. Elektrot.*, No. 6, 1929, Vol. 21, pp. 535–562.)

The materials included glass, steatite and paper. For a very slow increase of voltage (1 kv. per minute) the breakdown voltage is practically constant up to a certain temperature and then drops exponentially. The writer concludes that on the part of the curve which is independent of temperature, the breakdown is an entirely electrical effect, while on the other part it is a heat effect.

NEW INVESTIGATIONS INTO THE FUNCTIONING OF MERCURY RECTIFIERS.—J. v. Issendorff. (*E.T.Z.*, 25th July, 1929, Vol. 50, pp. 1079–1086; Discussion, pp. 1099–1101.

RECTIFICATION OF HIGH TENSION ALTERNATING CURRENT BY MEANS OF A STRIATED-DISCHARGE CIRCUIT.—T. Itoh. (*Proc. Imp. Acad.*, Tokio, No. 1, 1929, Vol. 5, pp. 5–14.)

Description and investigation into the action of a special form of point-to-plate discharge gap with a circular glass plate between the electrodes, the whole being in an atmosphere of 6.20 cm. pressure. In another form, the glass plate is replaced by a liquid dielectric.

MODERN POWER RECTIFIERS (A.E.G.).—(*A.E.G. Mitt.*, March, 1929, No. 3, pp. 79–86.)

A series of papers on the glass-bulb and ironclad rectifiers, for currents up to 400 A. or thereabouts, now being produced.

HOCHSPANNUNGS-GLEICHSTROM-MASCHINEN DER A.-G. BAYERISCHE ELEKTRIZITÄTS-WERKE IN LANDSHUT (High Tension Direct Current Generators made by the Bavarian Electrical Works at Landshut).—(*Zeitschr. f. Hochf. Tech.*, July, 1929, Vol. 34, pp. 27–28.)

Among the types illustrated and briefly described are :—16 kw. at 1,440 r.p.m., 4,500 v., two poles only, which gives several advantages, *e.g.*, small diameter commutator which is strong mechanically ; weight only 715 kg. ; a complete motor-generator set, 3 kw. at 2,940 r.p.m., 3,000 v. ; generators with three commutators giving high, medium and low voltage d-c, two slip-rings giving 50 cycle a-c, and provision for a small supply of 800 cycle a-c ; a filament supply motor-generator set giving 500 A. at 17 v.

SUR LES PILES À ÉLECTROLYTE FONDU : LA PILE OXYDE DE CUIVRE-SOUDE CAUSTIQUE FONDUE-ZINC (Cells with Molten Electrolyte : the Copper Oxide—Molten Caustic Soda-Zinc Cell).—G. I. Costeanu. (*Comptes Rendus*, 1st July, 1929, Vol. 189, pp. 35–37.)

"This cell would be useful for its high E.M.F. [about 1.3 v.] and constant output, if the zinc were not strongly attacked even on open circuit."

DAS MINIMALIMPEDANZRELAIS (Minimum Impedance Relays).—H. Puppikofer. (*Bull. de l'Assoc. Suisse des Élec.*, 7th May, 1929, Vol. 20. pp. 249–267.)

EIN EINFACHES VERFAHREN ZUR ABKÜRZUNG DER BELICHTUNGSZEITEN BEI PHOTOGRAPHISCHEN AUFNAHMEN (A Simple Way of Shortening the Exposure in Photographic Recording).—F. Ebert. (*Zeitschr. f. anorg. Chem.*, No. 1/3, 1929, Vol. 179, pp. 279–280.)

A saving of 50 to 70 per cent. of the exposure can be obtained by warming the film to 40°.

A NEW SIGNAL RELAY.—C. T. Burke. (*Rad. Engineering*, March, 1929, Vol. 9, pp. 38–39.)

A relay operating on one milliampere (its d-c resistance being 1,500 ohms) and following impulses of frequency up to 125 per second. An unusual feature is the wide pole-gap (0.47 inch), giving a uniform field in the region through which the reed moves, and making the adjustment to the neutral position less critical than in other relays. The tungsten point contacts will break one ampere without burning.

MACHINE FOR INTEGRATING A FUNCTIONAL PRODUCT.—K. E. Gould. (Abstract in *Science Abstracts*, Sec. B, 25th June, 1929, p. 332.)

MAGNETIC TESTING FURNACE FOR TOROIDAL CORES.—G. A. Kelsall. (*Journ. Opt. Soc. Am.*, July, 1929, Vol. 19, pp. 47–49.)

A furnace designed to eliminate the difficulty in maintaining the insulation between turns of the magnetising and exploring windings, and between the windings and the test sample, during tests at high temperatures.

STATIONS, DESIGN AND OPERATION.

THE PROBLEMS OF RADIO SERVICING.—J. F. Rider. (*Rad. Engineering*, June, 1929, Vol. 9, pp. 63–66.)

This, the third paper of a series, deals with general valve voltage and current tests indicating specific faults in the receiver.

MEASUREMENT OF WAVELENGTHS OF BROADCASTING STATIONS.—R. Braillard and E. Divoire. (*E.W. & W.E.*, Aug., 1929, Vol. 6, pp. 412–421.)

An account of the work of the Brussels Checking Station of the U.I.R., with diagrams and photographs of the apparatus. There is a section on the Accuracy of Measurements (which points to an accuracy of the order of one or two parts in 10,000 in the measurement of wavelength) and on the Measurement of "Scintillation" or variation of carrier frequency due to modulation. This is dealt with by obtaining a heterodyne note of about 1000 p.p.s. and causing it to beat with a similar note from a tuning fork so as to give, not zero beat, but a note of a few cycles per second, which is rectified, amplified and recorded side by side with a seconds pendulum record.

THE ROUTINE MEASUREMENT OF THE OPERATING FREQUENCIES OF BROADCAST STATIONS.—H. L. Bogardus and C. T. Manning. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1225–1239.)

Authors' summary :—The method of making "zero beat" measurements of the operating frequencies of broadcast stations in the Second Radio District is described, showing the method of comparing the received signal from a broadcasting station with a signal of known frequency, obtained from a 10-kc multivibrator controlled by a 90-kc quartz crystal. There is also given a description of the method used in reducing the measurement to a flexible routine procedure while still maintaining an accuracy well within the 500-cycle limit established by the Federal Radio Commission.

THE PRAGUE CONFERENCE.—(*P.O. Elec. Eng. Journ.*, July, 1929, Vol. 22, pp. 126–128.)

This paper prefaces the reprint of the Prague allocation of wavelengths by a short history of the

preceding state of affairs, and remarks that "this is the first time that the Governments of European States have concurred in the wider, more humanitarian view that the last comer, or the smallest State, is entitled to share in the artistic and cultural benefits of Broadcasting, and that a distribution of wavelengths based on the essential needs of the countries concerned should take the place of the more crude policy of grab."

TOUR D'EUROPE RADIOPHONIQUE (A Tour of Broadcasting Europe).—A. Surchamp. (*QST Franç.*, Aug., 1929, Vol. 10, pp. 53–60.)

The countries dealt with in this instalment are Belgium, Holland, Denmark, Norway and Sweden.

COMMON WAVE BROADCASTING: PHASE-COMPENSATION OF THE CONNECTING LINES.—(German Patent 475375, Int. Stand. Elec. Corp., pub. 23rd April, 1929).

Effects resembling fading may be caused by differences in the lines, etc., conveying the synchronising waves to the various stations. The invention deals with motor-driven phase-adjusters for insertion at suitable points between the stations.

COMPULSORY WIRELESS AT SEA.—(*Wireless World*, 31st July, 1929, Vol. 25, pp. 101–102.)

An article on the new International Convention recently drafted. The obligatory provision of d.f. apparatus, the importance attached by the Conference to the "automatic watcher" or auto-alarm, and the prohibition of telephony on waves near 600 metres, are referred to.

WIRELESS TELEPHONY DEVELOPMENTS.—(*Engineer*, 26th July, 1929, Vol. 148, p. 83.)

A paragraph dealing with the recent wireless telephone communication between the "Berengaria" and Paris, between the "Bremen" on her maiden voyage and Germany; with the projected installation of short-wave telephony on the "Leviathan," and with the opening of the service between London and Buenos Aires.

WIRELESS TELEPHONE SET FOR LIGHT AEROPLANES. (*Engineer*, 26th July, 1929, Vol. 148, p. 93.)

A paragraph on a set brought out by the Marconi Company "to enable owner-pilots and clubmen to communicate while in flight with ground stations." The set weighs about 60 lbs. complete, and uses 75 watts from a wind-driven generator.

RÉCEPTION À ONDES COURTES, TYPE S.F.R.—POUR GRAND TRAFIC TÉLÉGRAPHIQUE ET TÉLÉPHONIQUE (Type S.F.R. Short Wave Reception for Heavy Telegraphic and Telephonic Traffic).—(*Bull. de la S.F.R.*, March–April, 1929, No. 3, pp. 59–68.)

S.F.R. SHORT WAVE TRANSMITTER FOR LONG DISTANCE TELEGRAPHY (15 kw. TO THE AERIAL) AND TELEPHONY (9 kw.).—(*Bull. de la S.F.R.*, June and July, 1929, pp. 111–120 and 135–152.)

NEW SHORT WAVE STATIONS IN U.S.A.—(*Nature*, 10th Aug., 1929, Vol. 124, p. 241.)

A paragraph on the two new stations in New Jersey, giving 4 channels, 2 to Europe, 1 to S. America, and 1 for experimental purposes. Wavelengths are 16, 22 and 33 m. The receiving sets have 2 stages r-f, 6 of intermediate and one of l-f amplification. Limits are assigned to the closeness to which motor-cars can approach the stations.

INTERFERENCE-ELIMINATION BY THE BAUDOT-VERDAN SYSTEM.—(*Journ. Télégraph.*, March and April, 1929, Vol. 53, pp. 49–53 and 73–77). *See* Abstracts, 1928, Vol. 5, p. 406.

In the present paper Carpentier's modification of the Verdan apparatus, and the extension of the principle to the synchronising currents, are dealt with.

GENERAL PHYSICAL ARTICLES.

ON TIME-LAGS IN FLUORESCENCE AND IN THE KERR AND FARADAY EFFECTS.—E. Gaviola. (*Phys. Review*, June, 1929, Vol. 33, pp. 1023–1034.)

The following are some of the conclusions reached:—(*a*) The idea of the existence of time-lags in fluorescence was probably conceived because of a misunderstanding of the concept introduced by Bohr, that excited atoms can live for finite time without radiating. There is not a single experiment which shows the existence of such a lag. (*b*) The optical shutter of Beams, which was supposed to "open abruptly, remain open any desired time from 10^{-9} to 10^{-7} seconds and then close abruptly," is analysed and found to open and close during a time of the order of 10^{-8} sec. and to remain open for at least 10^{-8} sec. in the best case. The time during which it remains open does not depend in first approximation on the position of the "trolley" as was assumed. It is concluded that the light wave-trains assumed by Lawrence and Beams to be cut in pieces of 3 cm. length were really not shortened to less than 300 cm. in the best case. (*c*) The time-lags found for the Kerr effect in liquids with high dielectric constants were probably due to the fact that increase in dielectric constant means increase of the capacity of the Kerr condenser and consequently of the time that it takes to discharge [Beams and Lawrence have already stated that there is no evidence of a lag of Kerr effect behind rapidly changing electric fields—*see* Abstracts, 1928, Vol. 5, p. 587].

ON THE IONIZATION OF HYDROGEN BY ITS OWN RADIATIONS.—J. Thomson. (*Phil. Mag.*, June, 1929, Vol. 7, No. 46, pp. 970–980.)

REPORT ON THE WORK OF THE BARTOL RESEARCH FOUNDATION, 1928–9.—W. F. G. Swann. (*Journ. Franklin Inst.*, Aug., 1929, Vol. 208, pp. 189–258.)

ÜBER WIDERSTANDSÄNDERUNG VERSCHIEDENER METALLE IN MAGNETFELDERN (The Resistance-Change of Various Metals in Magnetic Fields).—F. Vilbig. (*Arch. f. Elektrot.*, 15th June, 1929, Vol. 22, No. 2, pp. 194–219.)

ANALYSE VON ABSORPTIONSKURVEN FÜR ALLSEITIGE INZIDENZ INHOMOGENER STRAHLUNG BEI EBENEN GRENZFLÄCHEN (Analysis of Absorption Curves for Incidence from every direction of inhomogeneous Radiation at Plane Surfaces of Separation).—H. Hellmann. (*Physik. Zeitschr.*, 1st June, 1929, Vol. 30, No. 11, pp. 357–360.)

DE VERHOUDING VAN IONISATIE EN AANSLAG BIJ DE BEWEGING VAN ELECTRONEN DOOR NEON (The Relation between Ionisation and Excitation by Electrons moving in Neon Gas).—F. M. Penning and M. C. Teves. (*Physica*, April, 1929, Vol. 9, pp. 97–110.)

Preliminary experiments are described concerning the number of excitations and the number of ionisations in neon gas caused by electrons moving in a homogeneous electric field. This relation is expressed as a function of the quotient of the electric field by the pressure of the gas.

THE SCATTERING OF FAST ELECTRONS BY ATOMIC NUCLEI.—N. F. Mott. (*Proc. Roy. Soc.*, 4th June, 1929, Vol. 124 A, pp. 425–442.)

The scattering of a beam of fast electrons by an atomic nucleus is investigated, using the wave equation of Dirac. A scattering formula is obtained, and it is found that the scattered beam is polarised. A method by which this polarisation could be detected is discussed.

A PROPERTY OF SUPERCONDUCTING METALS.—J. H. Bartlett. (*Nature*, 8th June, 1929, Vol. 123, pp. 869–870.)

A suggested explanation of the disappearance of the residual resistance at the threshold temperature. In a following letter, P. Kapitza comments on the suggestion.

DIE ROLLE DER LEITUNGSELEKTRONEN BEIM FERROMAGNETISMUS (The Rôle of the Conduction Electrons in Ferro-magnetism).—J. Dorfman and R. Jaanus. (*Zeitschr. f. Phys.*, 4th April, 1929, Vol. 54, No. 3/4, pp. 277–296.)

As a result of theoretical treatment of tests on the thermo-electric and magnetic properties of nickel, the ferro- and para-magnetic properties of this metal are found to depend entirely on the conduction electrons. "For the first time, the numerical value of the moment of spin of the conduction electron in a metal has been successfully measured. It comes out at one Bohr magneton, within 5 per cent." The number of conduction electrons in nickel depends on the temperature: this number can be directly calculated for various temperatures.

CRYSTAL STRUCTURE AND FERROMAGNETISM.—O. v. Auwers. (*Phys. Zeitschr.*, 15th December, 1928, Vol. 29, pp. 921–927.)

The Heisenberg quantum-mechanics theory of ferromagnetism is here considered in conjunction with a large number of published results, which are found to agree with the theory.

THE CORONA DISCHARGE IN NEON.—L. G. H. Huxley. (*Phil. Mag.*, July, 1929, Vol. 8, No. 48, pp. 128–129.)

Referring to Penning's paper (August Abstracts, p. 464) the writer quotes his own preliminary tests which suggest that Penning's methods must have led to results vitiated by impurities in the gas used.

PROEVEN OVER PERSISTEERENDE STROOMEN (Tests on Persistent Currents).—W. Tuyn. (*Physica*, May, 1929, Vol. 9, No. 5, pp. 145–160.)

A description of experiments on the persistent currents in supra-conductors.

SPARKING CONSTANT IN AIR.—M. Toepler: K. May. (*Arch. f. Elektrot.*, 15th February, 1929, Vol. 21, pp. 433–442 and 467–470.)

By keeping the electrode capacity as small as possible so as not to distort the surge wave form, Toepler reduces the sparking constant to 0.15×10^{-3}. May confirms that the constant is independent of atmospheric pressure from one to one-tenth atmosphere: his value agrees with the above.

FUNKENKONSTANTE UND LUFTTEMPERATUR (Sparking Constant and Air Temperature).—M. Toepler. (*Arch. f. Elektrot.*, 15th July, 1929, Vol. 22, No. 3, pp. 243–244.)

Continuing his previous work, the writer now finds that the sparking-constant k is approximately inversely proportional to the absolute temperature of the air surrounding the gap.

ÜBER DIE MÖGLICHKEIT EINES EXPERIMENTELLEN NACHWEISES DER GEGENSEITIGEN VERNICHTUNG VON ELEKTRONEN UND PROTONEN (On the Possibility of an Experimental Indication of the Mutual Destruction of Electrons and Protons).—C. Lönnqvist. (*Zeitschr. f. Phys.*, 5th July, 1929, Vol. 55, No. 11/12, pp. 789–800.)

The writer concludes that the idea of mutual destruction by collision of electrons and protons, suggested by Eddington as a hypothetical source of cosmic energy, could be tested in the laboratory by bombarding an acid with beta or cathode rays.

DAS WESEN DER HÖHENSTRAHLUNG (The Nature of the Cosmic Rays).—W. Bothe and W. Kolhörster. (*Zeitschr. f. Phys.*, 16th August, 1929, Vol. 56, No. 11/12, pp. 751–777.)

The full paper concerning the tests dealt with in September Abstracts, p. 523.

ÜBER MÖGLICHE URSACHEN DER VERWANDLUNG VON ENERGIE IN MATERIE (Possible Causes of the Transmutation of Energy into Matter.)—G. I. Pokrowski. (*Zeitschr. f. Phys.*, 5th July, 1929, Vol. 55, No. 11/12, pp. 771–777.)

A continuation of the writer's work on the Synthesis of Elements (Sept. Abstracts, p. 523). "It is shown that in interstellar space about 10^{-10} of the total energy must be changed per second

into matter. It is also shown that the light from the spiral nebulæ shows a displacement towards the red indicating a condensation of radiant energy into matter."

GAMMA AND COSMIC RAYS.—J. A. Gray and A. J. O'Leary. (*Phys. Review*, No. 2, 1929, Vol. 23, p. 292.)

Summarised report based on tests with gamma rays. One of the conclusions reached is that the methods of calculation from observed data, as usually applied, lead to too great values for the intensity of the cosmic rays.

THE SCATTERING OF RADIATION BY FREE ELECTRONS ON THE NEW RELATIVISTIC QUANTUM DYNAMICS OF DIRAC.—O. Klein and Y. Nishina. (*Zeitschr. f. Phys.*, No. 11/12, 1929, Vol. 52, pp. 853–868.)

The result obtained calls for a modification of the wavelengths of the cosmic rays estimated from the scattering coefficients on the assumption of the Dirac-Gordon result.

LIQUID DIELECTRICS UNDER HIGH FIELD STRENGTHS AND AT HIGH TEMPERATURE.—A. Nikuradse. (*See* two papers in *Arch. f. Elektrot.*, 15th July, 1929, Vol. 22, No. 3, pp. 283–324.)

ÜBER DIE DIELEKTRIZITÄTSKONSTANTEN EINIGER METALLDÄMPFE (On the Dielectric Constants of some Metal Vapours).—F. Krüger and F. Maske. (*Physik. Zeitschr.*, 15th May, 1929, Vol. 30, No. 10, pp. 314–320.)

NEW DIMENSIONAL EQUATIONS FOR ELECTRICAL AND MAGNETIC QUANTITIES.—P. Kalantaroff. (*Rev. Gén. de l'Élec.*, 16th February, 1929, Vol. 25, pp. 235–236.)

Instead of time, length and mass, the writer uses as dimensions time, length, quantity of electricity and magnetic flux, and evolves four groups of equations relating to electrical, magnetic, electromagnetic and some mechanical magnitudes. The forms of these new equations suggest certain fields of speculation which he discusses.

MISCELLANEOUS.

UNTERSUCHUNGEN AN DETEKTORKONTAKTEN (Investigations into Contact Detectors).—F. W. Kallmeyer. (*Ann. der Phys.*, Series 4, Vol. 86, No. 12, 1928, pp. 547–586.)

The characteristics of a large number of contacts, crystal and also metal to metal, were plotted using chiefly a 50-cycle frequency and varying contact-pressures. The interesting results include the frequent occurrence of characteristics with hysteresis loops, the variation of characteristic when external conditions remain constant, and the frequent occurrence of negative contact-resistances.

NEUERE UNTERSUCHUNGEN ZUM DETEKTOR-PROBLEM (New Investigations into the Crystal Detector Problem). R. H. Elsner. (*Rad., B., F. für Alle*, Aug., 1929, pp. 342–347.)

The article begins with a description of Kallmeyer's work (see above) on the recording of the dynamic characteristics of a number of crystal detectors. Ettenreich's results on the inertia-free working of a crystal lead one to expect practically no difference between the static and dynamic characteristics, so that Kallmeyer's records showing anomalies of the nature of hysteresis are surprising. The conclusions drawn by him from this and other results are discussed. The results of Beck (April Abstracts, p. 226), Habann (July, p. 403) and Reissaus (*ibid.*) are mentioned, and the writer sums up these recent results as confirming Schottky's electronic theory and extending it thus:—the detector current is a purely electronic flow which takes place between two electrodes separated by a dielectric inter-layer; the intermolecular processes have an important effect on the shape of the characteristic, in that materials with firmly attached ions give good rectification, while a wandering of ions within the contact-point weakens the rectifying property.

INFLUENCE OF TEMPERATURE ON LUMINOUS CARBORUNDUM CONTACT: ON THE APPLICATION OF THE QUANTUM THEORY TO THE PHENOMENON OF LUMINESCENCE OF A CRYSTAL DETECTOR.—O. V. Lossev. (*T. i T.b.p.*, No. 2, 1929, Vol. 10, pp. 153–161.)

In Russian.

METALLIC CONTACT RESISTANCES: CHARACTERISTICS OF CONTACT RESISTANCES.—E. and R. Holm. (*Wiss. Veröffent. a.d. Siemens Konz.*, No. 2, 1929, Vol. 7, pp. 217–271 and 272–304.)

The full papers describing the exhaustive series of researches referred to in April Abstracts, p. 227.

ÜBER DIE BEEINFLUSSUNG DES MENSCHLICHEN ORGANISMUS BEIM ARBEITEN AM KURZWELLENSENDER (The Effect on the Human Organism of Work with Short Wave Transmitters).—K. Heinrich. (*E.T.Z.*, 25th July, 1929, Vol. 50, pp. 1088–1090.)

As a result of reports from America of disturbances to health resulting from such occupation, the writer carried out a series of tests independent of, but almost at the same time as, those of Schliephake (June Abstracts, p. 347). He worked with two transmitters, giving 44 m. and 2–4 m. waves; anode current 0.2 A. in both transmitters. The magnetic field, so far as could be detected, produced no effects—though in the case of the shorter waves this may possibly be due to the fact that the oscillating circuit contained only one half turn. The electric field between the condenser plates showed the usual marked biological effects. The distribution of the field between the plates was investigated by thermometers, and the effect of varying the gap was examined. Air and glass (in strips) were here used as dielectrics. Comparing these results with the biological tests, the author concludes that the biological effects must be due, *not* to the a-c field, but to radiation.

Röntgen ray effects from the valve filaments were investigated and found, more readily in the case of parallel plate anodes than for cylindrical anodes. But the most original result, confirmed

by repeated observations, was the disturbing effect on a water diviner who happened to be giving a demonstration near the aerial of the 44 m. transmitter. He could neither see nor hear the transmitter, and had no means of telling when it was off or on; but each time it transmitted it affected his divining twig.

BIOLOGICAL EFFECTS OF ULTRA-SHORT WAVES: DIELECTRIC LOSS IN ELECTROLYTE SOLUTIONS IN HIGH FREQUENCY FIELDS.—W. T. Richards and A. L. Loomis. (*Proc. Nat. Acad. Sci.*, July, 1929, Vol. 15, pp. 587–593.)

Schereschewski explains the lethal action of short waves (e.g. on mice) by the theory that certain wavelengths act specifically on cells, but Christie and Loomis and other workers believe that all effects produced on animals can be fully explained on the basis of heat generated by the h.f. currents induced in them. In support of this explanation, the present paper discusses the behaviour of electrolytes in h.f. fields. A simplified expression is derived (from an unpublished theorem of G. W. Pierce) connecting power loss in a liquid dielectric with its conductivity, dielectric constant, and the frequency of the field. This has been tested and verified, and its application to physiological behaviour in high frequency fields is suggested.

The approximate equation derived for the power loss, valid for dilute electrolytes, is $p = \frac{A\omega\kappa}{B + D\kappa^2}$ where κ is the specific conductivity, the dielectric constant being assumed (for simplicity) to be constant. In the tests, wavelengths from about 1 m. upwards were obtained by methods described by Christie and Loomis (*Journ. Exper. Medicine*, 1929, Vol. 49, p. 303) and by Wood and Loomis (*Phil. Mag.*, 1927, Vol. 7, No. 4, p. 417).

CHARACTERISTIC FREQUENCIES IN WATER: EFFECT OF ELECTROMAGNETIC RADIATION ON ANIMAL TISSUES.—W. F. G. Swann: McDonald. (*Journ. Franklin Inst.*, Aug., 1929, Vol. 208, pp. 227–228.)

Referring to Bramley's results (Abstracts, 1928, Vol. 5, p. 587) it is pointed out that the same effect might occur in the tissues (e.g. in treatment of cancer by electromagnetic radiation). If the frequencies used coincide with the fundamental frequencies inherent in the structure of the tissue, very much greater absorption may be expected, with a resulting enhancement of the heating effect. This seems to fit in with observed results with animals.

NATURAL IONISING RADIATION AND RATE OF MUTATION.—E. B. Babcock and J. L. Collins. (*Nature*, 10th Aug., 1929, Vol. 124, pp. 227–228.)

The suggestion of Olson and Lewis that the natural ionising radiation of the earth plays an important part in evolution was tested by the writers by comparing results in their laboratory and in a tunnel 15 miles away, where the radiation was found to be fully twice as great as in the laboratory. The tests so far performed were on the rates of occurrence of sex-linked lethal mutations in *drosophila melanogaster*, and positive results were obtained. Even pending their further researches the writers consider it safe to conclude that this radiation is a very important factor controlling the rate at which new inherited characters originate in animals and plants.

SOME OF THE PSYCHOLOGICAL EFFECTS OF RADIANT ENERGY.—H. Laurens. (*Journ. Opt. Soc. Am.*, No. 3, 1929, Vol. 18, pp. 237–252.)

SUBSTRATUM COMMUNICATION AMONG WHITE ANTS.—A. E. Emerson and R. C. Simpson. (*Science*, 21st June, 1929, Vol. 69, pp. 648–649.)

Tests with a microphone and valve amplifier are described which convince the writers that ants communicate with each other (danger signals, etc.) by vibrations in the nest material produced by hammering their heads on it, possibly also by snapping their mandibles.

ALCUNE ESPERIENZE COLLE LAMPADE A NEON (Some Experiments with the Neon Lamp).—V. Ronchi. (*N. Cimento*, No. 1, 1929, Vol. 6, pp. 10–13.)

The experiments deal with the lighting-up of a neon lamp of medium candle-power merely by placing it in a variable field caused by electrical discharges. The sensitivity of the lamp, for the detection of such fields, is extraordinarily high.

SUDDEN UPWARD BEND OF CURRENT-VOLTAGE CURVE OF STRONGLY IONISED GAS AT ATMOSPHERIC PRESSURE.—R. Thaller. (*Physik. Zeitschr.*, 15th Jan., 1929, Vol. 30, No. 2, pp. 59–61.)

Usually the curve for a gas ionised by X-rays, ultra-violet light, etc., rises rapidly at first as the voltage increases, then more slowly till saturation is reached, and then becomes horizontal; for still higher voltages it rises rapidly again and a discharge takes place. The writer describes an experiment in which the gas was ionised very strongly by a Lenard tube: the curve started as a straight line sloping upwards, and then—without bending over to the horizontal—shot suddenly upwards and a discharge took place.

NOTE PRÉLIMINAIRE CONCERNANT MESURES DE LONGEUR PAR ONDES STATIONAIRES ÉLECTROMAGNÉTIQUES (Preliminary Note on the Measurement of Lengths by Stationary Electromagnetic Waves).—H. S. Jelstrup. (*Avh. Oslo*, No. 7, 1928, 9 pp.)

The note refers to a patented method of measuring bases for geodetic survey purposes. The theory and a description of the necessary apparatus is described.

DIE BEDEUTUNG DER DRAHTLOSEN TELEGRAPHIE FÜR DIE ANSTRICHTTECHNIK (The Significance of Wireless Telegraphy in the Paint Industry).—P. Nettmann. (*Farben-Zeitung*, 22nd June, 1929, Vol. 34, pp. 2238–2239.)

The application of radio technique to tests on paints is discussed. The Whiddington ultra-

micrometer can be used to determine changes in thickness of paint films on exposure to air, expansion by heat, etc., etc. Thoma has modified the method so that it will measure rapid changes; he uses two oscillatory circuits nearly in resonance; a slight change in one produces a very large change of current and voltage in the other. "With such an apparatus it has become possible to study processes of whose existence we had no suspicion."

Utesch's apparatus (Faraday cage and amplifier, working with a cathode-ray oscillograph) similar to that employed by Sauerbruch and Schumann in their study of electric fields in the neighbourhood of living beings, can be used in the study of electrification effects in sprayed paint. The effect of various radiations on paint can be studied with the aid of the Geiger ion-counter.

THE THOMA MODIFICATION OF THE ULTRA-MICROMETER.—(*Elektrot. u. Masch: bau*, 11th August, 1929, Vol. 47, p. 690.)

A description of the circuit referred to in the above abstract.

THE PROGRESS OF TECHNICAL PHYSICS IN CENTRAL EUROPE. (*Zeitschr. f. tech. Phys.*, June, 1929, Vol. 10, pp. 193–262.)

The whole of this number is devoted to the celebration of the tenth year of the German Society for Technical Physics. It includes, among other articles, the following:—E. Warburg.—The Relations between Theoretical and Technical Physics; H. Konen.—The Effect of Technical Physics on Pure Physics; H. Gerdien.—Objects and Duties of Technical Physical Research Institutes in Industry; C. Ramsauer.—Should the T-Ph. Research Laboratories of Industry carry on purely scientific Research? Various other authors deal with T. Physics in relation to different subjects, such as the optical industry, the chemical, glass, and iron industries, medicine, communication technique, etc., etc.

THE AMATEUR AND THE NAVAL RESERVE.—R. H. G. Mathews. (*QST*, August, 1929, Vol. 13, pp. 17–19.)

An outline of the organisation of the U.S. Navy "Volunteer Communication Reserve," which is divided into 14 districts, each with its Commander.

THE RELATION BETWEEN THE ELECTRIC AND MAGNETIC FIELDS OF A WIRELESS WAVE.—F. C. Curtis. (*E.W. & W.E.*, Aug., 1929, Vol. 6, p. 439.)

The writer says that although the problem has been clearly discussed by Dellinger, Moullin and others, the old fallacies about these fields and particularly about their effects on loops and open aerials are astonishingly persistent: he quotes a number of ambiguous statements by various eminent authorities which are liable to encourage and prolong the life of these ancient heresies among students who read such statements—*e.g.*, "One responds to the electric, the other to the magnetic oscillation" (Lodge).

WIRELESS AT THE AERO SHOW.—(*Wireless World*, 7th Aug., 1929, Vol. 25, pp. 127–129.)

DAS TONTELEGRAPHIE-SYSTEM DER C. LORENZ AKTIENGESELLSCHAFT (The Lorenz Note-Telegraphy System).—W. Scheppmann and A. Eulenhöfer. (*E.T.Z.*, 6th June, 1929, Vol. 50, pp. 815–817.)

MUTUAL INDUCTION BETWEEN CONDUCTORS OF FINITE LENGTH CONVEYING ALTERNATING CURRENTS.—F. Pollaczek. (*Ann. der Physik*, 18th Dec., 1928, Vol. 87, pp. 965–999.)

BEKÄMPFUNG DER RADIOGERÄUSCHE BEI ALUMINIUMSCHLEIFBÜGELN VON STRASSENBAHNEN (The Prevention of Radio Interference from Aluminium Current Collectors on Tramways).—R. Wichmann. (*E.T.Z.*, 13th June, 1929, Vol. 50, pp. 855–857.)

Trouble encountered with these collectors is *not* due to the aluminium. A suitably designed and properly adjusted aluminium collector produces no interference. Such design and adjustment (which also increase the life of the collector) are here described.

DIE FERNSPRECHSTÖRWIRKUNG VON GLEICHRICHTERBABNEN (Interference with Telephony caused by Railways, etc. using Rectified Currents).—L. Roehmann. (*E.N.T.*, July, 1929, Vol. 6, pp. 283–284.)

LA TRANSMISSION ÉLECTRIQUE À DISTANCE DES INDICATIONS DE MESURES, ET LA SYSTÈME À INDUCTION TÄUBER-GRETLER (Distance Transmission of Meter-readings, and the Täuber-Gretler System).—A. Imhof. (*Rev. Gén. de l'Élec.*, 10th August, 1929, Vol. 26, pp. 217–222).

The principles involved in the 11 or more different systems at present existing are first enumerated, the rest of the paper dealing in detail with the induction dynamometer system of Trub, Täuber and Company.

DISTANCE TRANSMISSION OF INSTRUMENT READINGS.—C. H. Linder and others. (*Journ. Am.I.E.E.*, March, 1929, Vol. 48, pp. 183–185.)

Among the various systems described, that employing Selsyn motors is included. This "motor" has a 3-phase stator and a single phase rotor; if several of them have their stators connected together, and their rotors are supplied with the same single phase current, all the rotors take up relatively identical angular positions and follow any movements imposed on any one of them. The system has the disadvantage of requiring three wires between stators, and a common source of a.c.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

MINIMISING "NOISE" IN SUPPLY MAINS.

Convention date (Germany), 14th January, 1928. *No.* 304148.

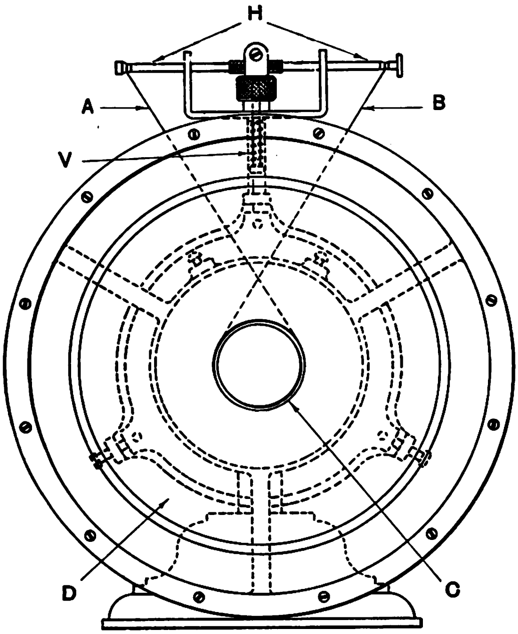
When high-frequency electro-medical apparatus, such as that used for diathermy, is energised from the electric light mains, it is apt to cause considerable disturbance to broadcast listeners in the vicinity. To minimise this source of disturbance, the supply leads to the spark-gap of the diathermy appliance are made electrically equal, for instance by inserting a choke-coil in one lead to compensate for the induction coil of the trembler contact in the other. Any high-frequency currents passing back into the mains accordingly flow in opposite directions and neutralise each other.

Patent issued to W. Otto.

LOUD SPEAKERS.

Application date, 25th January, 1928. *No.* 310441.

In a speaker of the moving-coil type, the coil *C*, together with the attached diaphragm *D*, is carried by one or more cords *A*, *B*, of silk from an adjustable suspension *V*, *H*. To damp the extreme freedom of axial movement, a steady-current component is superposed on the voice-frequency currents flowing in the coil windings. The ends of the suspension cords are secured to the opposite extremities of a horizontal pin *H*, which is screw-threaded for axial adjustment and is mounted on an upright screw *V* for vertical adjustment.



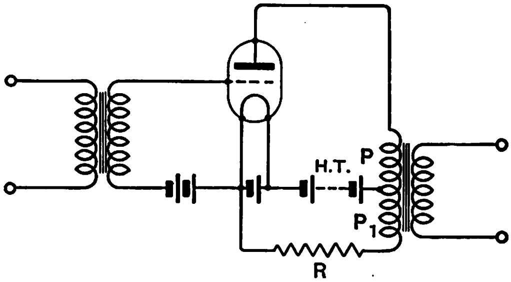
No. 310441.

Patent issued to O. D. Lucas.

TRANSFORMER COUPLINGS.

Application date, 20th March, 1928. *No.* 313229.

The presence of a direct-current component in the primary windings of the output transformer of a valve amplifier may cause the transformer to operate at an unfavourable point on the magnetisation curve. Also it tends to create "noise" due to residual ripple when a mains eliminator is used for the high-tension supply. The circuit arrangement shown is designed to balance out the effect of the D.C. plate component. The output primary comprises two oppositely wound parts P, P_1, the latter being short-circuited around the high-tension supply in series with a high resistance R. The value of the resistance is chosen so that in normal operation the ampere-turns in P and P_1 are equal. The induction is therefore reduced to zero, whilst any "ripple" that may be present in the H.T. source can have no effect on the secondary of the transformer.



No. 313229.

Patent issued to S. G. S. Dicker.

AN "ULTRADYNE" CIRCUIT.

Convention date (Germany), 28th October, 1926. *No.* 279861.

In "ultradyne" reception a local oscillator valve is employed to provide the only high-tension applied to the modulator or first detector valve. It is distinguished from super-heterodyne reception where the combination between the incoming signal and local oscillation takes place in the grid circuit of the first detector. According to the invention a three-electrode valve is used as the local oscillator, whilst a tetrode valve, having a space-charge grid, and no direct supply of high-tension, operates as the modulator to create an intermediate frequency for further amplification. Both stages may be housed inside the same glass bulb.

Patent issued to S. Loewe and W. Kunze.

MICROPHONES.

Application date, 17*th April*, 1928. *No*. 313706.

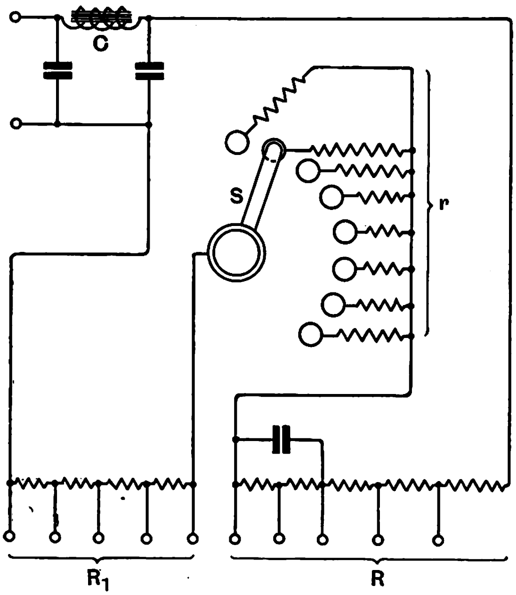
A thermionic valve is utilised as a microphone by causing a pivoted plate, suspended inside the bulb, to act as a variable screen between the filament and anode of the valve. The pivoted screening plate is made of iron, and is normally held clear of the electron stream by an external magnet. When speech or other vibrations are applied to the valve, the bulb moves bodily, and the screening plate is accordingly swung more or less into the direct path of the electron stream from filament to plate. The corresponding variations in output current are passed through the primary windings of a low-frequency transformer for further amplification.

Patent issued to A. F. and D. A. Pollock.

D.C. ELIMINATOR UNITS.

Application date, 17*th March*, 1928. *No*. 313722.

In order to secure steady plate and grid-biasing voltages, irrespective of filament consumption, the D.C. mains are shunted by a comparatively low resistance, which takes a constant current of approximately half an ampere. The resistance is made up of a solid-core smoothing-choke C of 100 ohms (for a 220-volt supply) in series with a resistance R tapped to give suitable plate voltages, a resistance R_1 tapped for grid bias, and the resistance of the valve filaments connected in parallel between R and R_1, the total resistance in circuit approximating to 500 ohms. In order to regulate the filament current taken by each valve, shunt resistances r are connected across the filaments, in combination with a regulating switch S. As the current drawn from the mains is constant under all operating conditions, the voltage taps maintain a steady value.



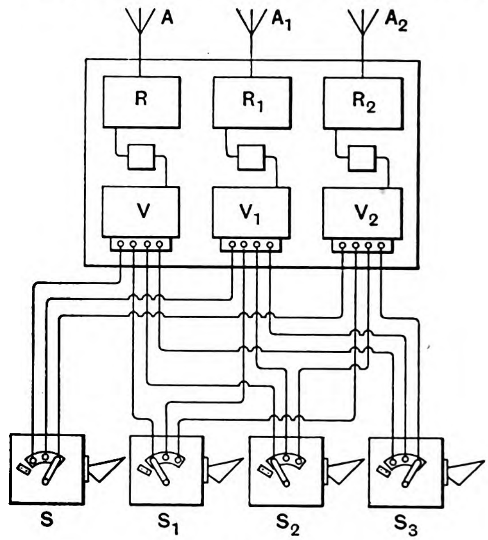
No. 313722.

Patent issued to P. Bruynseraede.

DISTRIBUTING BROADCAST PROGRAMMES.

Application date, 11*th February*, 1928. *No*. 311450.

A number of aerials $A - - A_2$ and selective receiving sets $R - - R_2$ are located at some central spot away from interference and under the charge of one or more skilled operators. Each receiver is tuned to a definite transmitting-station, and all are connected through amplifiers $V - - V_2$ and land-lines to a circle of subscribers $S - - S_3$ in such a way that each subscriber can switch in to any desired programme at will. It is pointed out that such a system would relieve listeners of the initial outlay on equipment as well as the trouble of maintenance. Local aerials and interference due to "oscillation" by unskilled listeners would accordingly disappear. Finally the reception of programmes would be limited to those who had duly paid for the service.



No. 311450.

Patent issued to S. Richardson.

BAND-FILTER COUPLINGS.

Application date, 23*rd April*, 1928. *No*. 314167.

In order to cut out any high-frequency components present in the output from the detector valve, the latter is coupled to the low-frequency amplifier by a chain of series resistances shunted by condensers, the network forming a low-pass filter of economical construction. The condensers are ganged together for simultaneous control. The chain of resistances may consist of three elements of the order of 10,000 to 250,000 ohms. A construction of high-pass band filter consisting of a number of condensers in series each shunted by high resistances is also described.

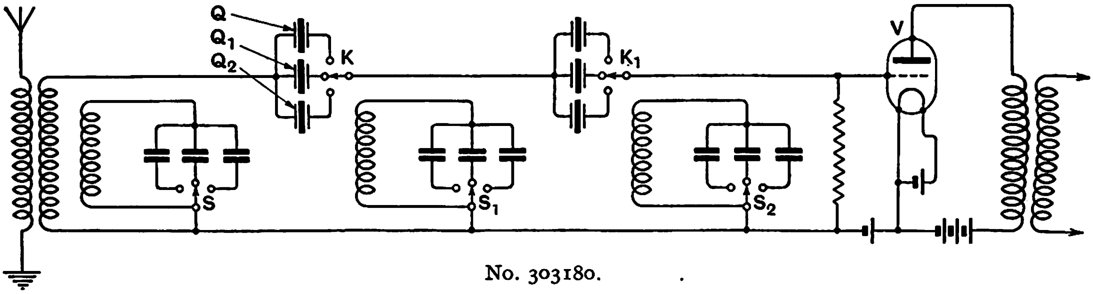
Patent issued to E. Y. Robinson and Metropolitan Vickers Electrical Co., Ltd.

PIEZO-CRYSTAL RECEIVING CIRCUITS.

Convention date (*U.S.A.*), 29*th December*, 1927. *No.* 303180.

A receiving circuit which will admit a band of frequencies comprising the carrier-wave and essential side-band components, but which has a sharp "cut-off" for all frequencies lying outside this band, depends for its action upon the use of a number of piezo-electric crystals in combination with relatively simple filter circuits. The circuit is capable of adjustment up and down the frequency scale. As shown in the Figure, the input circuit to a valve *V* comprises two groups of differently tuned crystals, such as the group marked Q, Q_1, Q_2, inserted in series in the grid lead and combined with a number of tuned rejector circuits. Tuning is effected by means of switches *K*, K_1 controlling the selection of the appropriate crystal and by switches *S*, S_1, S_2 which select the corresponding condenser in the shunt rejector circuits. The use of the piezo-crystal units avoids difficulties inherent in the design of an equivalent inductance-capacity network, such as the standard type of Campbell band filter.

Patent issued to Standard Telephones and Cables, Ltd.



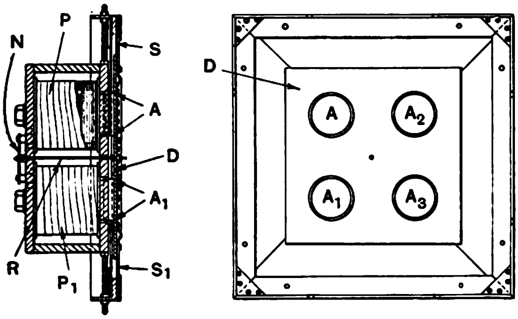
No. 303180.

LOUD SPEAKERS.

Application date, 13*th April*, 1928. *No.* 312756.

In order to impart a true plunger action to the diaphragm of a moving-coil speaker over as large an amplitude of swing as possible, four separate coils are wound on cardboard cylinders *A* ... A_3 mounted on the diaphragm *D* and co-operate with the pole pieces *P*, P_1 etc. of a 4-pole magnet. In this way the diaphragm is energised uniformly over a comparatively wide area. The coil windings may be connected in series or parallel. The diaphragm is suspended at its periphery by strips *S*, S_1 of thin leather, and is guided centrally by a spindle *R* centred at one end by spiders *N* or by a system of strings.

Patent issued to C. J. Nesbitt-Dufort and The O. and S. Oilless Bearings Co., Ltd.



No. 312756.

TELEVISION SYSTEMS.

Application date, 21*st April*, 1928. *No.* 311075.

Relates to television receivers of the type utilising a "glow light" board built up of a number of glow-lamps corresponding to each element of the picture and energised in synchronism with a pick-up device at the transmitting end. In order to secure intermediate light and shade effects, each of the lamp elements, when once illuminated by the incoming signals, is arranged to continue to glow for a short predetermined period after the cessation of the signal, so as to increase the light intensity. The frequency of illumination is varied as between the dark and light portions of the transmitted picture.

Patent issued to A. Carpmael.

VALVE CATHODES.

Convention date (*Germany*), 14*th March*, 1927. No. 287098.

Cathodes for thermionic valves are manufactured by depositing barium oxide on a thin wire of platinum or nickel in the following way: a mixture of alkaline-earth carbonates is suspended in methyl alcohol, through which a stream of carbon dioxide is passed. This deposits a methyl compound which is filtered off and mixed with water so as to produce a colloidal dispersion of the alkaline-earth carbonate. The wire to be coated is dipped into this liquid preparation and then connected to an electric current source, in series with a tubular anode. A low terminal voltage is used so as to produce an "electrophoretic" action whereby the colloidal particles drift towards the wire cathode and form a strongly adherent coating of barium carbonate which is then "glowed" to convert it into the oxide.

Patent issued to E. Harsanyi.

DRY CONTACT RECTIFIERS.

Convention date (*Germany*), *24th May*, 1927. *No.* 291026.

When using oxidized-metal rectifiers it is desirable that the applied pressure between the plates should remain constant, as otherwise the resistance of the surface-contact will change and so give rise to fluctuations in output. In practice it is difficult to maintain a steady pressure owing partly to temperature expansion and partly to the expansion caused by the flow of current when the rectifier is in operation. According to the invention this difficulty is overcome by making the central bolt, on which the rectifying elements are strung, of a bronze or nickel alloy, the temperature coefficient of which is identical with that of the copper-oxide rectifying elements.

Patent issued to Siemens and Halske, A.G.

QUARTZ OSCILLATORS.

Convention date (*Germany*), *18th March*, 1927. *No.* 287175.

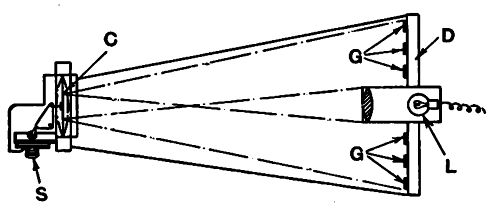
It is difficult to use quartz crystals for the direct control of high-powered transmitters owing to the deleterious effect of the heat generated upon the permanency of the crystal. According to the invention advantage is taken of the fact that the dimension of the crystal can be increased considerably in a direction at right-angles to the electric axis without affecting its fundamental frequency. A large crystal section cut in this fashion can accordingly be mounted between metal electrodes of considerable size, such electrodes owing to their comparatively large surface area will function effectively as cooling radiators.

Patent issued to H. Eberhard and Radio Frequenz, G.M.B.H.

OPTICAL GRAMOPHONE-REPRODUCER.

Application date, *31st October*, 1928. *No.* 314126.

The movement of the stylus *S* is transmitted to a diaphragm *C* at the centre of which is deposited, chemically or electrically, a spot of silver which acts as a reflector. A lamp *L* is mounted in the centre of another disc *D* carrying a ring of light-sensitive cells *G*, and projects a ray of light on to



No. 314126.

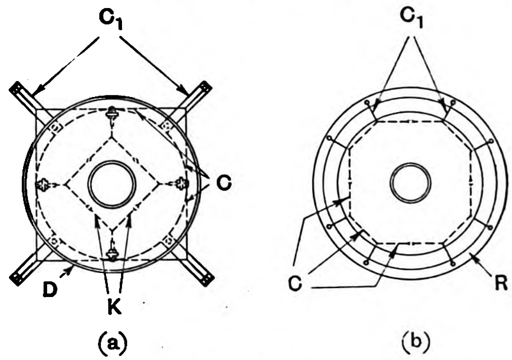
the centre of the diaphragm *C*. As the stylus is vibrated by the record, variations occur in the intensity of the light reflected back from the diaphragm *C* to the light-sensitive cells *G*, so giving rise to corresponding electric currents. The various component parts are all mounted on the tone arm.

Patent issued to J. Neale.

LOUD SPEAKERS.

Application date, *15th March*, 1928. *No.* 313646.

A conical diaphragm is supported by a system of tangential strings in such a way that it can move freely in an axial direction—*i.e.*, parallel to the



No. 313646.

impulses applied to it by the moving-coil or other driver, and at the same time is equally free to respond to flexural vibrations which take place in the material of the cone itself. The suspension prevents any movement as a whole in a direction at right-angles to the axis of the cone.

As shown in Fig. (*a*) the cone *D* is supported by an outer series of cords *C* lying tangential to a plane through the cone near its outer end. The string suspension *C* forms a square system, the four corners of which are connected by other cords C_1 to arms suitably mounted on the base plate. A second similar string suspension *K* may be arranged near the narrow end of the cone. In Fig. (*b*) the string suspension *C* is octagonal in shape, each corner being attached to a fixed ring *R* by strings C_1.

Patent issued to D. H. Johnson.

TELEVISION SYSTEMS.

Convention date (*U.S.A.*), *14th September*, 1927. *No.* 297078.

In order to overcome the known difficulty of televising an extensive field of vision, such as a street scene or tennis match, where only natural lighting is available, a kinematographic film is first taken by photographic means, and, simultaneously, the photographic film is scanned by a rotating disc and a light-sensitive cell so as to transmit equivalent light-modulated signals to the distant receiving station, where the received signals are reassembled by a rotating-disc analyser and projected directly upon a viewing screen. Alternatively the received signals may first be impressed upon a kinematographic film and then projected optically. The whole process of transmission and reception is effected in a continuous train, the necessary photographic and television apparatus being assembled in both instances as a complete unit.

Patent issued to Electrical Research Products Inc.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. NOVEMBER, 1929. No. 74.

Editorial.

The Definition of Selectivity.

IN our issue of August, 1929, we published a paper by Mr. Colebrook under the above title, and it will, we think, be very generally agreed that it is highly important that a definition of selectivity should be arrived at, particularly at this time when the matter is becoming so much the concern of those whose business it is to design receivers for broadcast reception where the outstanding requirements are the utmost attainable in selectivity without loss in quality of reproduction.

In introducing his paper Mr. Colebrook stated "Selectivity is a very important circuit characteristic. There is, however, no universally accepted definition of this term, which is capable of general application to all cases of electrical resonance. Such terms and formulæ as are at present in use have been derived from the theory of the simple series resonant circuit and are not in a form which makes clear their application to some of the more complex types of resonance which are utilised in wireless practice."

The introduction of the Regional Scheme of Broadcasting in this country certainly helps to focus attention on this subject as far as the broadcasting services are concerned. Dr. R. T. Beatty, in *The Wireless World* of October 16th, 1929, also deals with the problem of selectivity, and states "The discussion of selectivity has been hampered in the past by lack of an exact definition of the term." In the article Dr. Beatty shows a method by which the selectivity of any receiver can be expressed as a numerical quantity and that having arrived at this value the H.F. resonance curve of the receiver can be readily drawn.

In the same issue as Mr. Colebrook's paper we commented editorially on his views and criticised certain of his suggestions. To these criticisms Mr. Colebrook replied in a letter published under Correspondence in our September number, and the concluding sentence of his letter reads: "My views were put forward mainly with the idea of stirring up comment and suggestion." It is to this invitation which we would particularly draw the attention of our readers. We feel that at this time it would be helpful if readers who have made a study of the subject would contribute their views for publication in the hope that these may assist in arriving at final agreement on the definition of selectivity.

INDEX TO THE VOLUME.

With our December number, as has been our custom in the past, we shall publish the complete index to the year's volume, including the detailed index to the *Abstracts and References* to technical radio literature of the world.

At the end of the year the opportunity occurs to invite our readers to offer suggestions as to any particular features which they would like to see incorporated with the new volume. Criticism will be welcomed equally with suggestions.

The Numerical Estimation of Grid Rectification for Small Signal Amplitudes.

By W. A. Barclay, M.A.

In a former paper * it was shown that for all but very small signal amplitudes, the slope of the grid current characteristic when plotted logarithmically might be regarded as an index of detecting efficiency as far as the grid circuit of the valve is concerned. Since, however, a merit of the "cumulative grid" method of rectification is its sensitivity to small signal amplitudes, a rapid means of utilising the grid characteristic to estimate detecting efficiency for such small signals may not be without interest.

In dealing with small signals, we may conveniently assume an exponential form for the grid current characteristic, so that its logarithmic plot will be a straight line. The objections to this procedure when large signals are involved were considered in the paper referred to; for small signals the exponential curve will be sufficiently accurate. Groeneveld and others have proposed the formula

$$i_g = I_{g0} \cdot \epsilon^{\frac{v_g - V_{g0}}{V_T}} \quad \ldots \quad \ldots \quad (1)$$

where the variables are indicated by lowercase italics and the valve constants by capitals.† In this formula V_T is termed the "temperature voltage," and is stated to be, roughly, 0.1 v. for oxide filaments, 0.18 v. for thoriated filaments, and 0.25 v. for tungsten filaments. This formula is undoubtedly very convenient when it is desired to express a characteristic in terms of a given pair of related values I_{g0} and V_{g0} which satisfy the curve. Nevertheless, one of the constants is redundant, as will be seen by rewriting the equation

$$i_g = \left(I_{g0} \cdot \epsilon^{-\frac{V_{g0}}{V_T}}\right) \cdot \epsilon^{\frac{v_s}{V_T}} \quad \ldots \quad (2)$$

where the bracket term is itself a constant. In this paper we shall use the equation

$$i_g = a \cdot \epsilon^{\frac{v_g}{V_T}} \quad \ldots \quad \ldots \quad (3)$$

as being simpler than formula (1). a is, of course, the bracket factor of equation (2).

Using the symbolism adopted by the present writer in his former paper, we shall denote by v_0 the initial value of grid potential prior to signal reception. We may then write

$$\frac{v - v_0}{R} = a \cdot \epsilon^{\frac{v_0}{V_T}} \quad \ldots \quad \ldots \quad (4)$$

where v is the positive bias voltage applied and R is the leak resistance. Again, denoting by v_s the mean value of potential assumed by the grid during reception of a C.W. signal of amplitude E, we shall have

$$\frac{v - v_s}{R} = \frac{1}{T}\int_0^T a\epsilon^{\frac{v_s + E\sin\omega t}{V_T}} \, . \, dt \quad (5)$$

$$= a\epsilon^{\frac{v_s}{V_T}} \cdot \frac{1}{T}\int_0^T \epsilon^{\frac{E\sin\omega t}{V_T}} \, . \, dt \quad (6)$$

It has been remarked by Mr. C. R. Cosens‡ that the mean value integral of equation (6) is the imaginary Bessel Function $J_0\left(j\,\frac{E}{V_T}\right)$, values of which are tabulated in Jahnke & Emde's "*Funktionentafeln*." For most purposes, however, a sufficiently close approximation to its value may be obtained by using the "three-ordinate" method described by the writer (*art. cit.*, p. 464). Thus we may rewrite equation (5)

$$\frac{v - v_s}{R} = \tfrac{1}{3}\left\{a\epsilon^{\frac{v_s - .866E}{V_T}} + a\epsilon^{\frac{v_s}{V_T}} + a\epsilon^{\frac{v_s + .866E}{V_T}}\right\}$$

$$= a\epsilon^{\frac{v_s}{V_T}} \times \tfrac{1}{3}\left\{1 + 2\cosh\frac{.866E}{V_T}\right\} \quad (7)$$

Equations (4) and (7) afford us a theoretical means of calculating v_0 and v_s, and hence arriving at $\Delta = v_0 - v_s$, the required change of mean grid voltage due to rectification of signal E. Unfortunately, neither of these equations is in a form convenient for determining v_0 and v_s, and hence of Δ when E is given. It is therefore believed

* *E.W. & W.E.*, Aug. and Sept., 1927.—W. A. Barclay—Grid Signal Characteristics.

† See *E.W. & W.E.*, Sept., 1928—A New Idea for a Detector Valve.

‡ *E.W & W.E.*, Vol. II, p. 994.

that a rapid means of obtaining $\triangle$ from the valve and circuit data would be of service to experimenters, who generally have little time for calculations of the complexity necessitated by the above equations. The writer has, accordingly, taken advantage of the Alignment Principle to show how $\triangle$ and E may be conveniently and accurately related for all values of circuit and valve constants, on the assumption of the exponential law of (3). In order to do this, let us rewrite equations (4) and (7) in terms of symbols V and $\triangle$ defined as follows:

$$V = v - v_0$$
$$\triangle = v_0 - v_s$$

We have, from (4)

$$\frac{V}{R} = a\epsilon^{\frac{v-V}{V_T}}$$

$$i.e.,\ \log_{10}V - \log_{10}aR = \frac{v-V}{V_T}\,.\log_{10}\epsilon$$

$$i.e.,\ \frac{\log_{10}V - \log_{10}aR}{V - v} = -\frac{\log_{10}\epsilon}{V_T} \qquad .. \quad (8)$$

Again, from (7),

$$\frac{(v - v_0) - (v_s - v_0)}{R} = a\epsilon^{\frac{v_0 - (v_0 - v_s)}{V_T}} \times \tfrac{1}{3}\left\{1 + 2\cosh\frac{.866E}{V_T}\right\}$$

$$i.e.,\ V + \triangle = aR\epsilon^{\frac{v_0}{V_T}} \times \epsilon^{-\frac{\triangle}{V_T}} \times \tfrac{1}{3}\left\{1 + 2\cosh\frac{.866E}{V_T}\right\}$$

$$= V.\epsilon^{-\frac{\triangle}{V_T}} \times \tfrac{1}{3}\left\{1 + 2\cosh\frac{.866E}{V_T}\right\}$$

by equation (4).

$$i.e.,\ \left(1 + \frac{\triangle}{V}\right).\epsilon^{\frac{\triangle}{V_T}} = \tfrac{1}{3}\left\{1 + 2\cosh\frac{.866E}{V_T}\right\} \quad (9)$$

We shall now indicate a simple geometrical construction (in reality a form of the alignment process) by which V is determinable from (8). Knowing V we can then proceed to derive $\triangle$ by means of an alignment chart specially designed for the solution of (9).

Equation (8) is capable of geometrical interpretation as follows. If P denote a point whose cartesian co-ordinates are $(V, \log_{10} V)$ and Q a point whose co-ordinates are $(v, \log_{10}aR)$, the gradient of the line PQ will be the same as that of the line joining the points $(0, \log_{10}\epsilon)$ and $(V_T, 0)$. If, in Fig. 1 axes XOX' and YOY' be taken, the locus of the points P will be the curve $y = \log_{10}x$ as shown. Having given the valve constants a, V_T, and the circuit constants v, R, we proceed to find V as follows. Taking a point on the Y-axis $\log_{10}\epsilon$ above the origin, we join it to the value of V_T taken on the X-axis. Next seek the point Q of co-ordinates $(v, \log_{10}aR)$.

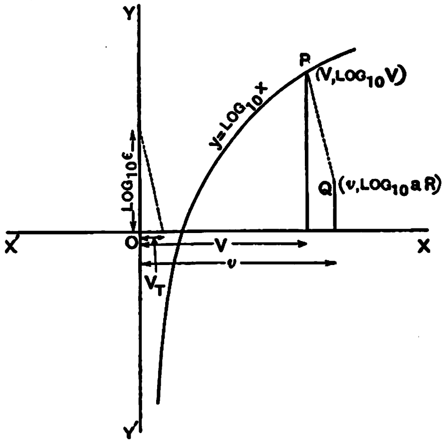


Fig. 1.

Through Q draw a line parallel to the first to meet the curve in P. The abscissa of P gives the value of V, the initial P.D. across the leak. It will be remarked that the diagram of Fig. 1 is permanently applicable to all grid characteristics (providing they are of exponential form) and does not have to be redrawn for individual cases. This universality of application is a feature of Alignment methods.

Having thus found V, we can proceed to the determination of $\triangle$ for signal E. This is effected by one or other of the two Charts, Figs. 2a and 2b, designed respectively for the alternative cases $E > V_T$ and $E < V_T$. Each chart has two vertical scales carrying values of the ratios $\frac{V}{V_T}$ and $\frac{E}{V_T}$, while the centre supports carry values of the ratio $\frac{\triangle}{V}$. Any straight line intersects all three scales in values related by equation (9) so that, in particular, when known values of $\frac{V}{V_T}$ and $\frac{E}{V_T}$

on the outer scales are joined, the value of $\frac{\triangle}{V}$ and hence of $\triangle$ is immediately ascertained. The facility with which Equation (9) may thus be solved for $\triangle$ provides a good example of the advantageous use of the Alignment Principle in the numerical evaluation of complex formulæ. The diagrams contain in compact form a wealth of statistical information about grid detection which is only otherwise obtainable with a disproportionate amount of arithmetical work. It is not too much to say that these methods, beautiful in their simplicity, will have a considerable future in wireless science, providing as they do a practical means of correlating three or more variables on a plane surface in cases where ordinary cartesian representation is quite inadequate. Their application to the correlation of experimental data has already been adumbrated by the writer in these pages.

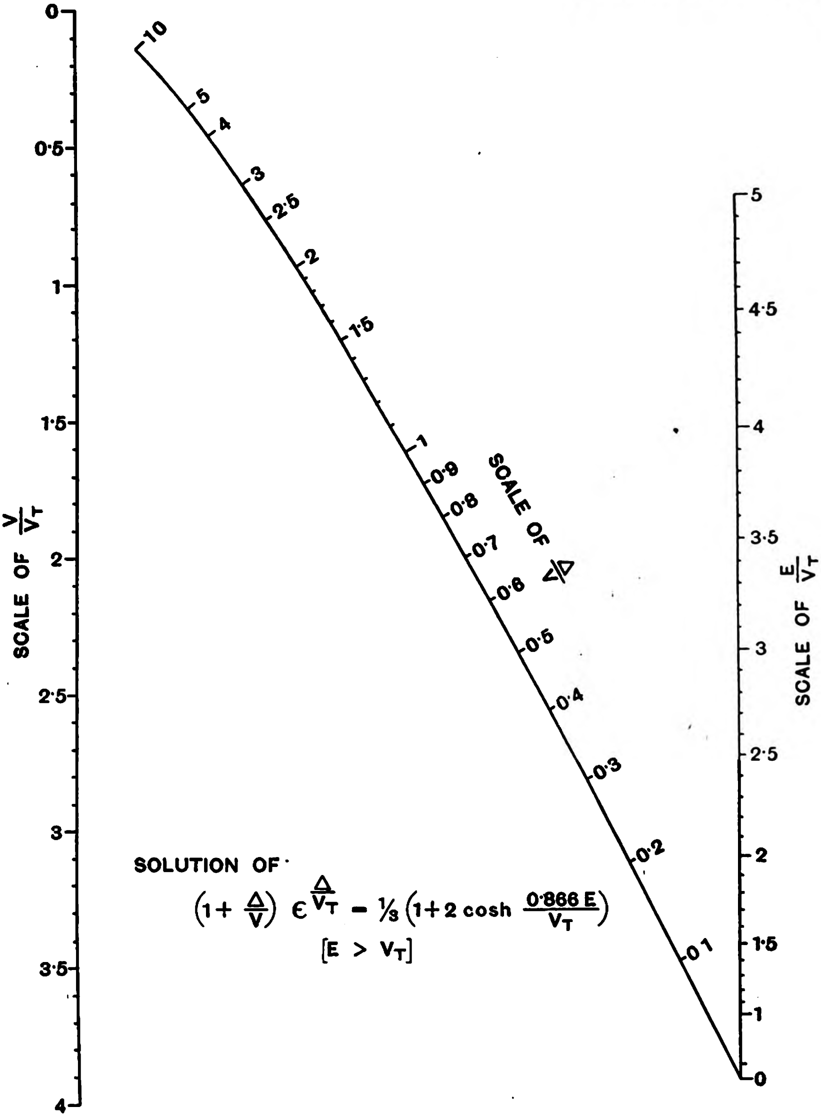


Fig. 2a.

As a practical example of the use of the foregoing diagrams, let us consider the effect on detection of potentiometer control of the voltage applied to the grid. Let us select a valve whose constants, as derived from the grid current characteristic, are $a = 0.88 \times 10^{-6}$ $V_T = 0.18$. (It should be observed in passing that the determination of these constants is an easy matter when the characteristic is plotted on semi-logarithmic paper. Its equation then becomes

$$\log_{10} i_g = \log_{10} a + \frac{v_g}{V_T} \cdot \log_{10} \epsilon$$

which is linear in v_g and $\log_{10} i_g$, so that the constants $\log_{10} a$ and $\frac{\log_{10} \epsilon}{V_T}$ are readily evaluated. It is worth noting that if i_g be taken in μA. and v_g in volts, the quantities a and V_T will also be expressed in μA. and volts respectively.) With the selected valve we shall use a leak resistance of 0.75 megohm, the filament end of which is connected

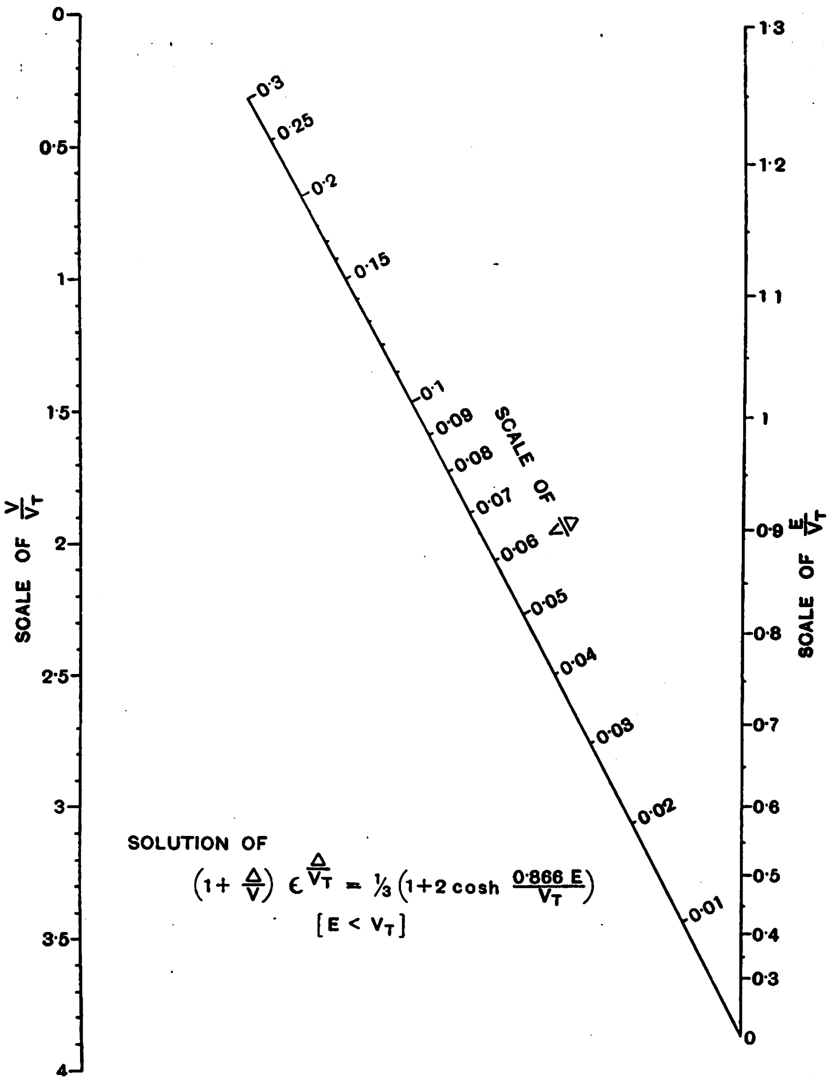


Fig. 2b.

and takes no account of the equally important anode circuit with which it is associated. Thus Δ is not, after all, the quantity with which we are primarily concerned. It is our ultimate aim to find the actual values v_0 and v_s of grid voltage prior to and during the passage of the signal, in order that the variations in anode current may be ascertained. Knowing V and Δ, however, this is a relatively simple matter, since by definition,

TABLE.

SHOWING VARIATION OF MEAN GRID POTENTIAL SHIFT Δ WITH GRID BIAS v FOR DIFFERENT SIGNAL VOLTAGE AMPLITUDES E.

$V_T = 0.18$ $a = 0.88 \times 10^{-6}$ $R = 0.75\ \Omega$

v	V	$\frac{V}{V_T}$	$E=0.1$; $\frac{E}{V_T}=0.55$		$E=0.2$; $\frac{E}{V_T}=1.11$		$E=0.3$; $\frac{E}{V_T}=1.66$		$E=0.4$; $\frac{E}{V_T}=2.22$	
			$\frac{\Delta}{V}$	Δ	$\frac{\Delta}{V}$	Δ	$\frac{\Delta}{V}$	Δ	$\frac{\Delta}{V}$	Δ
0	0.21	1.16	0.035	0.007	0.138	0.029	0.29	0.061	0.50	0.105
0.2	0.33	1.84	0.027	0.009	0.103	0.034	0.22	0.073	0.37	0.122
0.4	0.46	2.55	0.021	0.010	0.082	0.038	0.17	0.080	0.29	0.134
0.6	0.61	3.38	0.018	0.011	0.066	0.040	0.14	0.086	0.23	0.140
0.8	0.77	4.28	0.015	0.011	0.055	0.042	0.12	0.092	0.19	0.146
1.0	0.94	5.21	0.012	0.011	0.048	0.045	0.10	0.094	0.16	0.150

N.B.—The two last values of $\frac{V}{V_T}$ are found on Charts 2a and 2b by extrapolation, the $\frac{V}{V_T}$ scale being linear.

$$v_0 = v - V$$

and $$v_s = v_0 - \Delta$$

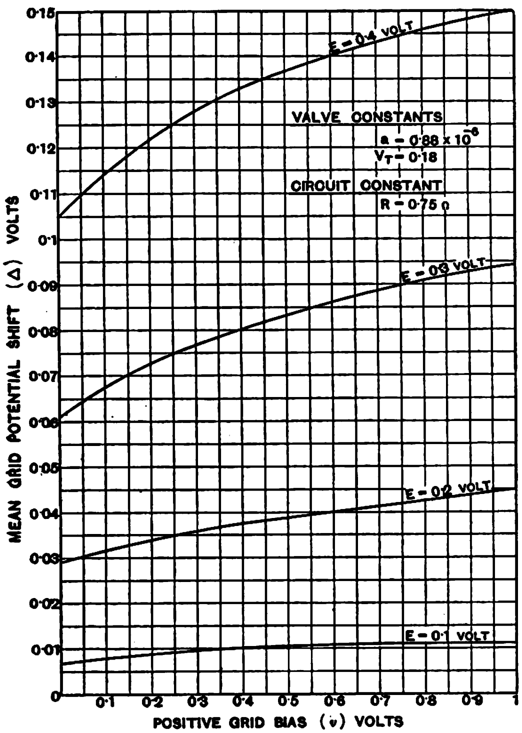


Fig. 4.—Variation of "Detection Efficiency" with Grid Bias for various signal amplitudes.

Physical and Optical Societies' Exhibition.

The Twentieth Annual Exhibition of Electrical, Optical and other Physical Apparatus is to be held by the Physical Society and the Optical Society on January 7th, 8th and 9th, 1930, at the Imperial College of Science and Technology, South Kensington.

In addition to a Trade Section and a new section for the work of Apprentices and Learners, there will be a Research and Experimental Section which will be arranged in three groups: (a) Exhibits illustrating the results of recent physical research; (b) Lecture experiments in Physics; (c) Historical exhibits in Physics.

The Exhibition Committee invites offers of exhibits from Research Laboratories and Institutions and from individual research workers. Offers of exhibits, giving particulars of space and other facilities required, should be communicated immediately to the Secretary, Exhibition Committee, 1, Lowther Gardens, Exhibition Road, London, S.W.7.

Moving Coil Loud Speakers.

By H. M. Clarke, B.Sc.

A PREVIOUS article* has shown the effect of a compensating winding for moving coil loud speakers with regard to the effective resistance and impedance.

In the same number, p. 365, Mr. C. R. Cosens discussed the ability of a compensating winding to effect a substantial reduction in the self-induction of the moving coil. Using this expression $2L(1-K)$ for the combined self-induction of moving coil and compensating winding, and making use of the curves on pages 381, 382, we see that L and $2L(1-K)$ have mean values of 0.2575 henries and 0.0152 henries respectively. This gives K equal to 0.9705, a value well within the effective zone.

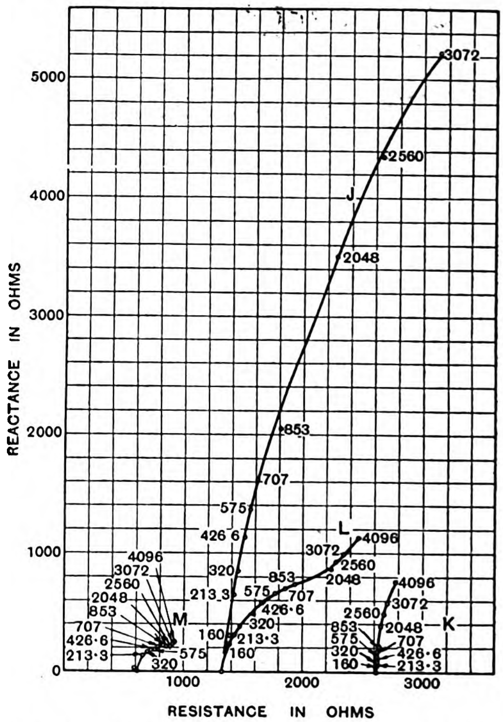
In the tests which were then described, the compensating winding was stated to be connected in series with the moving coil and therefore carried the same current. It was shown that a more uniform input could be obtained by a method of compensation which enabled the instrument to maintain approximately constant impedance and power factor under working conditions. The compensation consisted of coils concentrically situated with respect to the moving coil and fixed to the sides of the air gap, the fixed and moving coils being connected in series or in parallel in such a sense that they mutually opposed one another magnetically.

The question arises as to how far a compensating winding can effect its object if it is not electrically connected to the moving coil, but is shortcircuited so as to obtain its compensating current from the moving coil inductively, as if it were the secondary of a transformer.

The curves shown in the accompanying diagrams are the results of tests made without the polarising field, so that no sound was being emitted.

Curves J and K are for a 1,400-turn moving coil without compensation and with series compensation of 1,400 turns respectively. Curve L shows the electrical impedance characteristic of the same instrument with shortcircuited instead of series compensation, the shortcircuited secondary thus deriving its current inductively from the moving coil.

All curves were obtained from the same instrument with the same windings; the different conditions being obtained merely by changing the connections.



Vector impedance at frequencies varying from 0 to 4096. Working current 12 milliamperes A.C.

J = 1,400-*turn coil, uncompensated.*
K = 1,400-*turn coil,* 1,400-*turn series compensation.*
L = 1,400-*turn coil,* 1,400-*turn shortcircuited compensation.*
M = 1,000-*turn coil, copper cylinders compensation*.

Ratio	*Impedance at 4096* / *Resistance D.C.*	5.51
,,	,,	1.1
,,	,,	2.04
,,	,,	1.55

The moving system was not moved during or between the tests. The same alternating current strength was used for all readings,

* *E.W. & W.E.*, July, 1929, Vol. VI, No. 70.

which were obtained by means of a modification of Anderson's alternating current bridge best suited to the wide range of conditions prevailing during the tests.

Curve *L* shows that compensation in power factor can be obtained inductively only at the expense of increased resistance. In this case the impedance has an increase of 104 per cent. over the test range of frequency and compares with 450 per cent. and 10 per cent. for the uncompensated and compensated cases *J* and *K* respectively, the increase being due principally to increase of resistance.

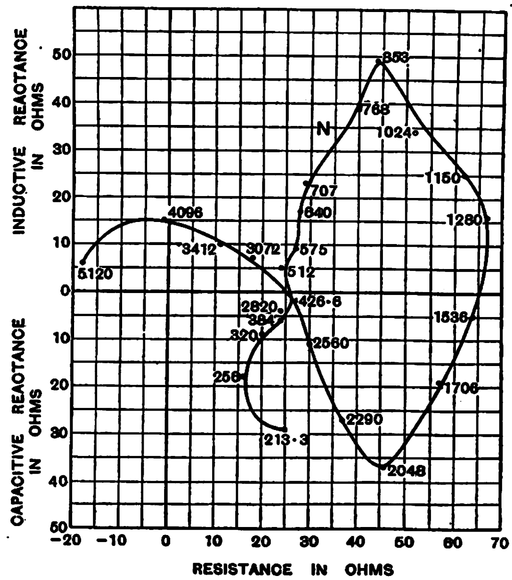
If, however, the compensation winding had a better conductivity, the compensating current could flow without requiring such an increase in the equivalent resistance of the moving coil. This improvement can be effected by making better use of the space available for the compensating winding. Another instrument was made having a moving coil of 1,000 turns and having the air gap lined on both sides with copper cylinders, each 0.5 millimetre thick. In this case the compensating winding consisted of two turns, one inside and one outside the moving coil with considerably more copper available for the secondary current.

The curve *M* shows the impedance of this instrument without its polarising field and is comparable with curve *L*. The increase of impedance is 55 per cent. compared with 104 per cent. for the same frequency variation.

It should be noticed that whereas series compensation tends to regulate for constant self-inductance and consequently for reactance proportional to frequency, induced compensation tends to regulate for constant reactance, and consequently for self-induction inversely proportional to frequency.

An important point in the case of induced compensation is that to reduce the effective secondary resistance the material and volume of the secondary winding must be the best possible.

In the case under consideration, using copper cylinders instead of enamelled wire, the effective area of cross section was increased fourfold. This advantage would have been neutralised if brass cylinders had been used, since the specific resistance of brass is not less than four times that of copper. The same effect would be produced by utilising only part of the polar surfaces as winding space. It is probable that still better compensation might be obtained by extending the copper secondaries to the iron surfaces immediately beyond the air gap sufficiently to ensure embracing all iron within the sphere of magnetic influence of



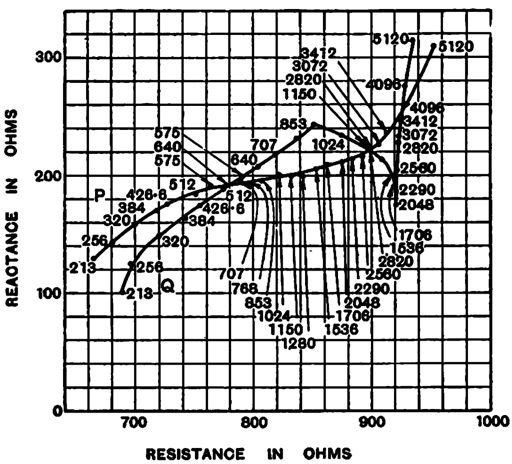
Vector difference of impedance with and without direct current field for 1,000-turn moving coil with copper cylinders compensation. Working current 12 milliamps. A.C.

the moving coil. This extra copper could be thicker than that in the air gap, where it can only be as thick as the gap permits. The copper external to the gap cannot, however, replace the copper in the gap, since the magnetic coupling between the moving coil and the external copper would be too loose to achieve anything but fractional compensation. The result would then be intermediate between the *J* and *M* cases.

In the inductively compensated cases, curve *M* shows that there is still considerable eddy current loss, so that the difference between impedances with and without the polarising field includes not only motional impedance but also the difference between the eddy current losses produced when the moving coil is stationary and when it is moving. In fact, the difference between the two resistances with and without field is the difference between the motional

resistance and the resistance equivalent to the recovered secondary losses. An interesting point to notice is that this difference may be negative without implying that there is no sound output, and it was found that such was the case above 4,000 frequency in the particular instrument under test. Curves *Q* and *P* show the vector impedances with and without the main field for the 1,000-turn moving coil instrument with copper cylinder compensation, and curve *N* is their vector difference. Curves *Q* and *P* should be compared with *B* and *D* of the previous article.

While it appears that induced compensation is not so effective in maintaining constant impedance as series compensation, it appears to keep the variation of impedance with frequency down to 250 per cent. for frequencies up to 10,000, and it has the advantage that it is not in electrical connection



Vector impedances of offset origin for 12 milliamps. A.C. in 1,000-turn moving coil with copper cylinders compensation.

P *without direct current field.*
Q *with direct current field.*

with the moving coil, thus facilitating the insulation of the latter from the body of the loud speaker. This is important in the case of a centre-tapped moving coil operating directly in the anode circuits of a push-pull output stage without the intervention of an output transformer.

This may be done without risk of a breakdown since the small wires used in high-resistance moving coil windings may be operated at very large current densities. The writer has had 1,000-turn coils of 47 S.W.G., carrying 50 milliamperes for hours continuously. Push-pull output valves may be biased to half-way along the lower bend of the anode current grid volts characteristic and there will then be no undue heating in a 1,000-turn coil of 47 S.W.G., even if six L.S.5A valves are used in parallel push-pull with a mean grid swing of 30 volts.

The use of an output transformer should be avoided if full advantage of the constancy of impedance and power factor of the instrument is to be taken. It is doubtful if the characteristics of such transformers are good enough not to exhibit considerable leakage reactance and in this event one of the advantages of compensation will be lost, namely, the rapid damping of transients.

Damping of transients and shunting of resonances can be used in the case of induced compensation with practically the same effectiveness as in the series case, since the resonant peaks to be shunted are so pronounced that the impedance of the filter circuit is required to rise on either side of the resonant frequency so rapidly that the impedance of the instrument over this range of frequency has changed but slightly, perhaps about 10 per cent.

A summary of the above results may be made as follows :—

The electrical input to the loud speaker may be made constant at all frequencies by means of a compensation winding, connected in parallel or in series with the moving coil or closed through current adjusting apparatus. The last case may take the form of copper cylinders in the air-gap and extending over the neighbouring iron of the magnet. The motional impedance, depending upon the method of suspension, and the mass of the moving system and upon the strength of the polarising field, will exhibit resonances.

These resonances may be smoothed most effectively in the case of the constant impedance instrument by means of an external shunting circuit tuned to the resonant frequency and having a resistance adjusted to give the desired shunting effect.

The values of the inductance and capacity of the shunting circuit may be chosen to give the required attenuation of the shunting effect. More than one shunting circuit may be used if more than one resonant peak requires smoothing.

Experimental Transmitting and Receiving Apparatus for Ultra Short Waves.

By R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E., and J. S. McPetrie, B.Sc. (National Physical Laboratory).

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(*Concluded from page 542 of last issue.*)

Part II (concluded).

(d) Short-wave Limit of Small Valve Oscillators.

It is quite simple to design and operate a 5-metre oscillator with ordinary receiving valves. Shorter wavelengths than this, however, become progressively more difficult to obtain until we reach a limit between 1.5 and 2 metres. Beyond this region it is practically impossible to make an oscillator using ordinary voltages on the electrodes. Two factors account chiefly for this limit. One is the capacity between the electrodes in the valve itself; this capacity is in shunt across the oscillatory circuit and so limits the range of the oscillator. The other is the finite time that the electrons take to pass from the filament to the anode. The period of the waves produced by the valve must be greater than this time in order that the current through the valve may respond rapidly to the changes in potential of the grid and anode. The table below gives the approximate dimensions of some typical valves.

VALVE DIMENSIONS.

Type.	Anode Diameter.	Grid Diameter.
French R.	0.85 cm.	0.4 cm.
British R. (old type)	0.9 ,,	0.45 ,,
,, ,, (new type)	1.0 ,,	0.40 ,,
D.E.R.	0.85 ,,	0.35 ,,
D.E.2 L.F.	0.52 ,,	0.25 ,,
D.E.2 H.F.	0.5—0.55 cm.	0.25 ,,
T.15	1.15 cm.	0.4 ,,
Shortpath G.	0.3—0.35 cm.	0.15 ,,
,, B.	0.3 cm.	0.15 ,,
,, RR.	0.3 ,,	0.2 ,,
P.M. 1 H.F.	0.5 ,,	0.15 ,,
P.M. 1 L.F.	0.55 ,,	0.2 ,,
P.M. 252	0.55 ,,	0.3 ,,
L.S. 5A	0.75 ,,	0.27 ,,
R.C. 2	0.6 ,,	0.25 ,,
G.P. 2	0.55 ,,	0.25 ,,
D.E.V.	0.7—0.75 cm.	0.3 ,,

It will be seen that 0.5 cm. is an average value for the diameter of the anode. This means that the electrons have to travel at least 0.25 cm. before the grid has time to change from one to the other half of its cycle of potential variation. In the modern receiving valve the temperature of the filament is so low that the initial velocity of the electrons from the filament may be neglected. We shall assume that the variation in potential of the grid is not large. This need not be true in all cases, but the analysis will be much simpler and quite approximate if we neglect this variation. Suppose the anode is at a potential of 50 volts above that of the filament. We can find the time of passage of the electron between the filament and the anode by the well-known equation

$$s = \frac{1}{2} at^2$$

where s is the distance traversed, a is the acceleration and t is the time during which the acceleration takes place.

In this case a is equal to $\frac{eV}{dm}$ where e and m are the electronic charge and mass respectively, V the potential between the anode and filament, and d the distance between anode and filament. Substituting the above values for V and d, this gives an approximate value of the time t of 1.2×10^{-9} secs. This time, as shown above, must be less than half the period of the wave, *i.e.*, the period of the oscillation produced by the valve must at least be 2.4×10^{-9} secs., the wavelength corresponding to which is 72 cms. Thus, we cannot hope to obtain oscillations of less than this wavelength with ordinary valves working under ordinary conditions.* Actually the limit found by a series of experi-

* *Cf.* H. E. Hollmann: "On the Mechanism of Electron Oscillations in a Triode," *Proc. I.R.E.*, 1929, Vol. 17, pp. 229–251.

ments was found to lie in the region of 1.5 metres. Fig. 12 shows a short-wave oscillator using circuit No. 11. The coils had a diameter of about 2 inches and no tuning condensers were used. The wavelength of this oscillator was about 1.7 metres when short-path valves were used. Fig. 13 is a photograph of another short-wave oscillator employing circuit No. 10. The coupling condensers had a maximum capacity of 100$\mu\mu$F and the wavelength of this oscillator was about 1.8 metres when the coil was in the form of an unclosed square, the length of side being 1.5 inches.

It will be noticed that the high-tension supply to the oscillator in Fig. 12 is by means of a thin wire (No. 47 S.W.G. copper). This wire at such high frequencies acts as a choke and also presents small capacity to neighbouring wires.*

* *Cf.* R. M. Wilmotte: "Self-inductance of Straight Wires," *E.W. & W.E.*, 1927, Vol. 4, pp. 355–358.

The two oscillators shown above suffered from a sort of fatigue. This may be due to the dielectric losses in the bases and glass wall of the valve. Fig. 14 is a curve in which the output from one of these oscillators is plotted against the time from the instant of starting the oscillator. The output was measured by inserting a thermo-junction in an untuned coil which was coupled to the oscillator. It will be seen that the amplitude of oscillations decreased by some 25 per cent. in three hours. After being switched off for a short time the oscillator output recovered its initial value.

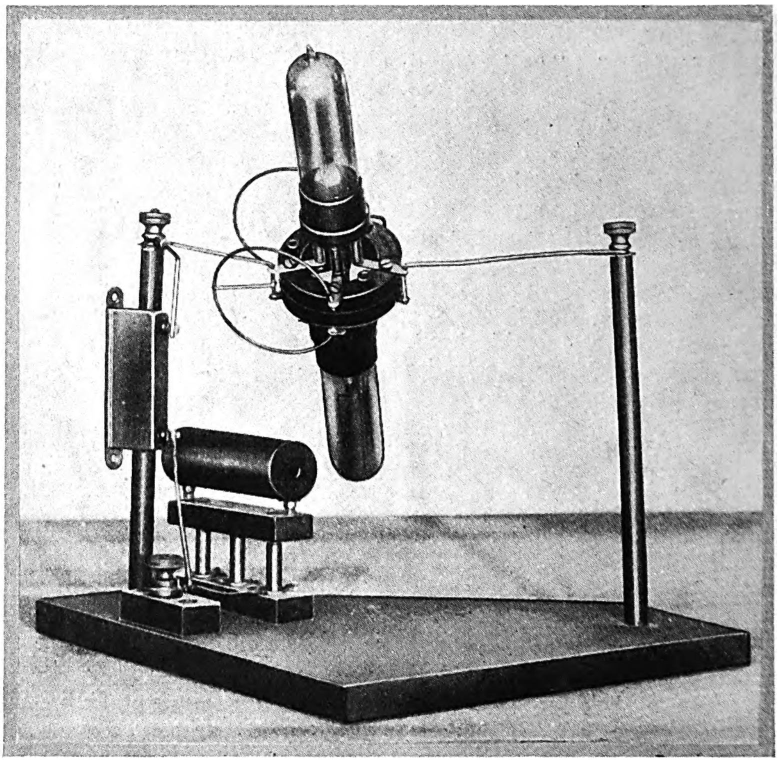


Fig. 12.—*Two-valve oscillator for a wavelength of 1.5 metres, using the circuit of Fig. 11.*

Part III.

Design and Development of Small Transmitters for Powers up to 1,000 Watts.

(a) Valve Requirements.

Valves intended to dissipate power at very high frequencies must have special design features not essential for those

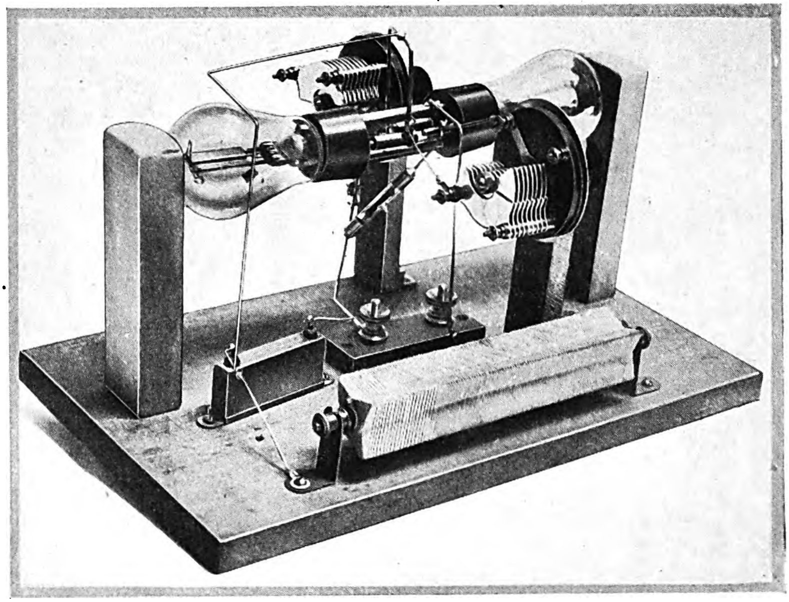


Fig. 13.—*Two-valve oscillator for wavelengths down to 1.8 metres, using circuit shown in Fig. 10.*

working at lower frequencies. The first feature we desire is low self-capacity and intercapacity of the electrodes. This means that the leads to the electrodes should be brought out as far as possible from one another. This separation of the leads, however, is limited by the inherent increase in inductance due to their greater length.

Several years ago Franklin* drew attention to the possibility of the glass envelope melting as a result of the heat generated by eddy currents in metallic deposits which occur on the inside of the glass during evacuation of the valve. In certain types of transmitting valves it has been customary to use copper foil screens on the outside to avoid breakdown from this cause.

The loss in a dielectric in an alternating field increases with the frequency of the field. The glass envelope of a valve lies within the field between the grid and anode. The envelope should, therefore, be of as great dimensions as is consistent with short leads from the electrodes. The neck of an ordinary valve is in a concentrated part of the field, and punctures were very common at this part when valves were first used on short wavelengths. The field may be reduced by continuing the grid mesh beyond the ends of the anode. This construction concentrates the radio-frequency field between the grid and anode and so reduces that which reaches the glass wall of the valve.† It is also

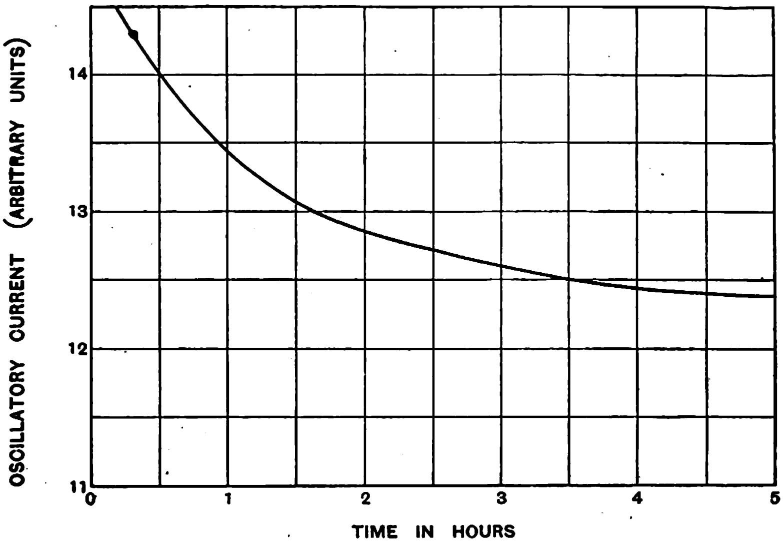


Fig. 14.—*Oscillator output.*

*C. S. Franklin: "Short Wave Directive Wireless Telegraphy," *Journal I.E.E.*, 1922, Vol. 60, pp. 930–934.

† Yojiro Kusunose: "Puncture Damage through Glass Wall of Transmitting Vacuum Tube," *Proc. I.R.E.*, 1927, Vol. 15, pp. 431–437.

advisable to thicken the leads to the electrodes at the places where they enter the glass.

(b) Circuit Layout of Transmitters.

We have designed several oscillators incorporating the circuits described in Part II. It is difficult to describe the different layouts in detail, but it is hoped that the typical photographs reproduced herewith will give a general idea of the methods adopted to obtain maximum efficiency. The valves were usually mounted on panels of American whitewood, this material having low dielectric loss when dry.

Fig. 15 shows an oscillator using circuit No. 9 with a 100-watt valve: as shown set-up in this photograph, a rejector circuit was incorporated in the grid-filament lead of the valve: this rejector circuit tended to oscillate and was later discarded. This oscillator with the coil and condenser shown in the photograph was capable of oscillating down to about 5 metres.

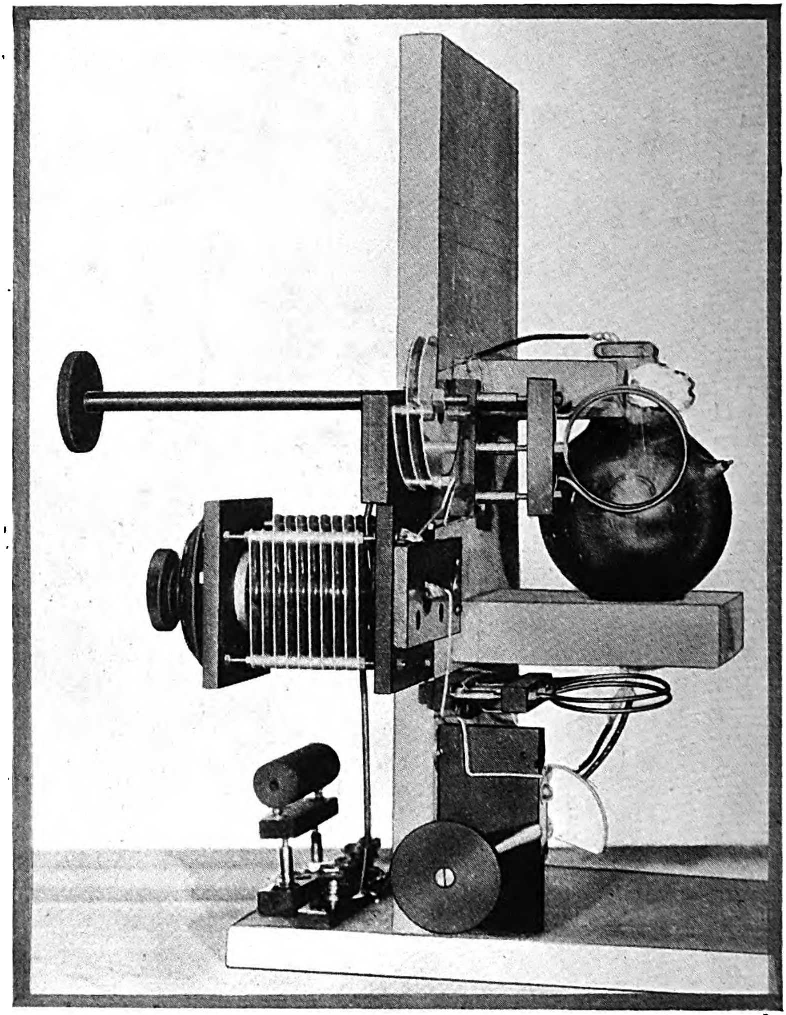


Fig. 15.—*Single valve transmitter employing* 100 *watt valve in the circuit of Fig.* 9 (*Series-fed Hartley Circuit*) *for wavelengths down to* 5 *metres. The lower coil forms part of a rejector circuit in series with the grid leak.*

A two-valve oscillator which could be used either with circuit No. 10 or 11 was built in order to compare the two circuits. The inconvenience of tuning two circuits when it was used as No. 11 decided us to concentrate on the single-coil capacity-coupled valves are mounted on opposite sides of a common panel of American whitewood in order to ensure the shortest possible leads from one valve to the other. It was found necessary to use chokes in series with the grid leaks to prevent leakage of high-

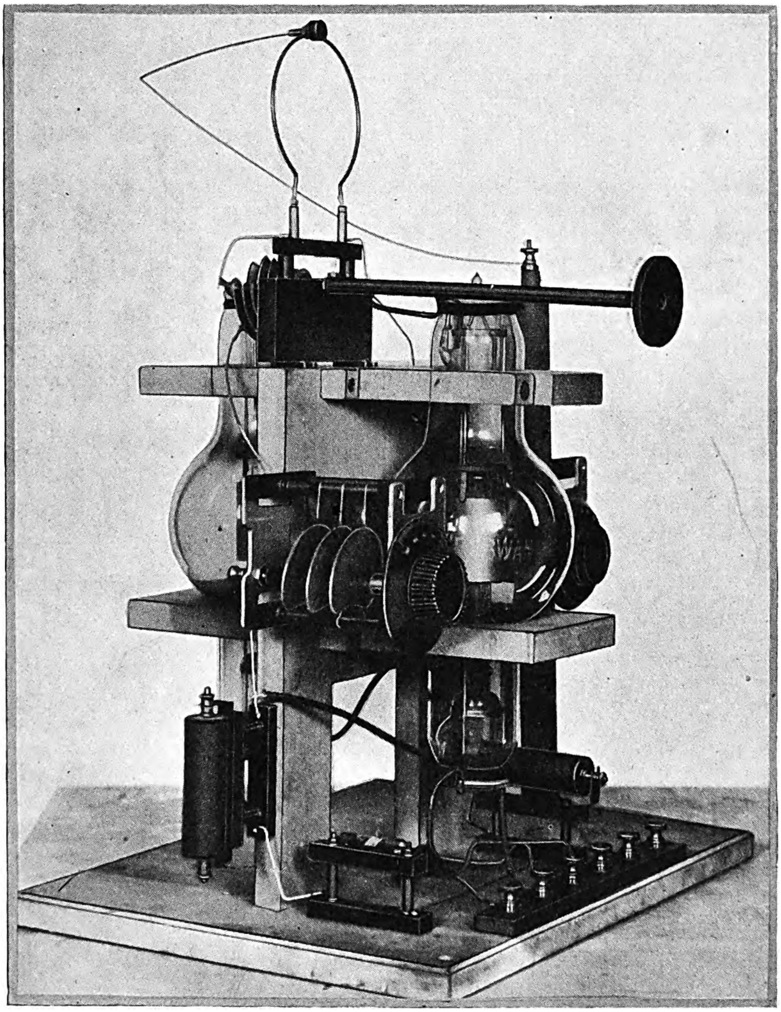


Fig. 16.—*Single-coil push-pull oscillator, using two 250 watt valves employing the circuit shown in Fig. 10 and operating on wavelengths from 5 to 20 metres, with interchangeable coils.*

push-pull transmitter with circuit No. 10. A typical oscillator of this type using two 250-watt valves is shown in Fig. 16. The tuning condenser had a maximum capacity of about $30\mu\mu F$ and the same size of condenser was used for coupling the anode of one valve to the grid of the other. The frequency power into the filament leads. This oscillator is shown in Fig. 17 under working conditions in a hut at the Radio Research Station, Slough. The valve filaments are operated from a 16-volt battery and the anode current is obtained from a D.C. generator at 2,000 to 5,000 volts. The

transmitter is shown in the photograph, Fig. 17, set up on a movable table which carries the valve control panel. When using two 250-watt valves at a high-tension supply of 3,000 volts, and a total input power of 300 to 400 watts, the circulating current in the inductance is several amperes at a wavelength of 6 or 8 metres. By moving the table variable coupling is obtained to a Lecher wire system connected to the external transmitting aerial. The construction of a similar transmitter employing two 500-watt valves is now in progress.

Two-valve circuits are used more frequently than single-valve circuits as, by the use of push-pull generators we can obtain greater output without increase in the high-tension voltage. This is particularly valuable when a portable transmitter is required.*

It has been shown above that circuit No. 10 is simply a combination of two No. 9 circuits. Sometimes in a push-pull circuit we may suspect that one of the valves is not oscillating. If this is the case the oscillator will be working as circuit No. 9. This can easily be verified by dimming the filament of each valve in turn. If the dimming of one filament stops the transmitter from oscillating there is a probability that the other valve is not oscillating when the transmitter is used in push-pull.

The above oscillators may be modulated by varying the potential of the grid in any of the usual ways. For work on

* *See* R. L. Smith-Rose and E. L. Hatcher: *The Wireless World*, 1928, Vol. 23, p. 501.

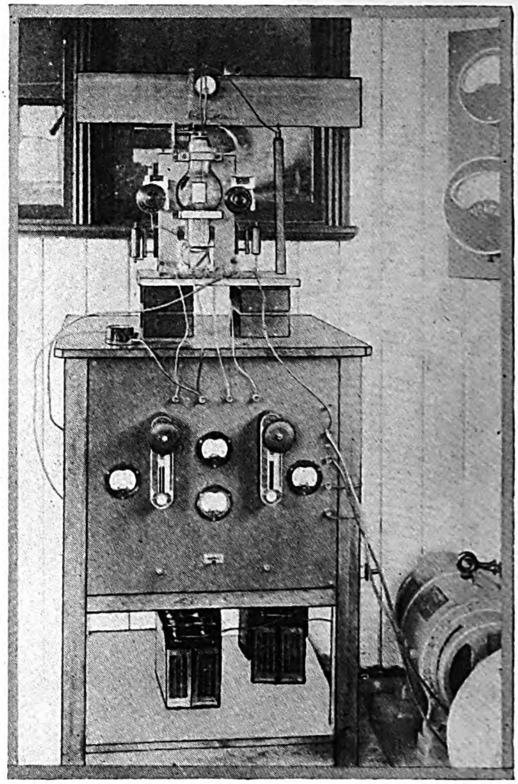
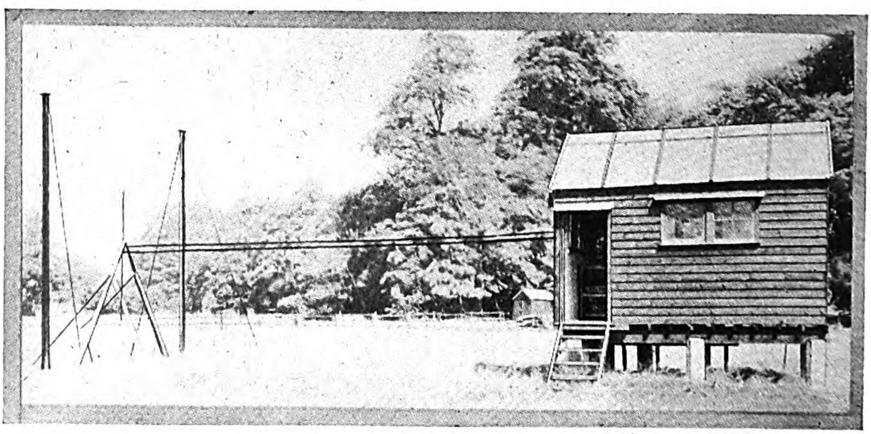


Fig. 17.—*The complete short-wave transmitter set up at the Radio Research Station, Slough. The oscillator is that illustrated in Fig.* 16, *and it supplies a half-wave antenna through the transmission line shown in the photograph below.*



The transmission line referred to in Fig. 17 *above.*

short waves we favour anode potential modulation as this removes the system of modulation from the high frequency end of the oscillator.

For the transmission of Morse signals it has been found that the operation of a key, one terminal of which is connected to a suitable point on the Lecher wire system, is convenient. The operation of the key imposes a lumped capacity on the Lecher wires thereby distuning them from the oscillator frequency. The resulting signals are clear-cut and free from "frequency-slurring" at make or break.

(c) Lecher Wires and the Measurement of Wavelength.

The simplest method of determining the wavelength of high-frequency oscillations is by means of Lecher wires. These may be described as two long parallel conducting wires short-circuited at the input end by a conducting bridge. If a sinusoidal oscillation is impressed at the input end of such a system stationary waves are set up in it. The velocity of propagation of these waves on the wires will be very nearly that of the velocity of similar waves in free space

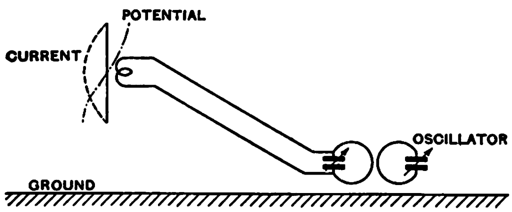


Fig. 18.—*Inductive supply to ungrounded $\lambda/2$ antenna.*

provided the wires of the Lecher system are good conductors and of a sufficient diameter to ensure that their inductance per unit length is not large. If these conditions are fulfilled the wavelength of the stationary waves will be very nearly equal to that of the oscillations impressed on the wires. The positions of the nodes and antinodes of current in the wires may be determined from the readings of a meter placed in a second bridge which may be moved along the wires. The distance between any two consecutive nodes or antinodes of current is half the wavelength of the stationary waves. These, however, as shown above, have the same length as those of the oscillator coupled to the Lecher wires. The measurement of the length of the stationary waves, therefore, gives us a determination of the wavelength of the oscillations of the transmitter coupled to the Lecher wires. Hund* has shown that a small condenser placed in parallel with the

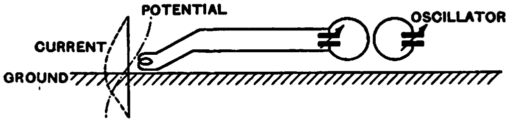


Fig. 19.—*Inductive supply to grounded $\lambda/4$ antenna.*

wires near their input end shifts the nodes and antinodes nearer the input end without affecting the distance between them. A variable condenser in this position may thus be used to bring the nodes and antinodes to convenient positions on the wires. This is particularly useful in transmission lines used to feed antennæ.

(d) Methods of Energising Antennæ.

The measurement of wavelength is not the only use to which Lecher wires have been put in short-wave installations. At high radio-frequencies the antenna either of a transmitting or receiving station should be situated in as open a space as possible. In a radiating field objects act as reflectors when their linear dimensions are comparable with the wavelength of the incident field. The buildings associated with a short-wave station are such that they give rise to this source of scattering and loss. The only method of diminishing this loss is to place the aerial at some distance from any buildings and to lead the energy to or from it by means of a transmission line. Most commercial short-wave transmitting and receiving stations are designed in this way. In feeding an antenna for transmission it is most efficient to make the load at the antenna end equal to the surge impedance of the transmission line. This prevents the reflection of the waves at the aerial end of the line and limits the current in the wires and so the ohmic loss in them.

The antennæ used in short-wave trans-

* A. Hund: "Theory of Determination of Ultra-radio Frequencies by Standing Waves on Wires," Bureau of Standards, 1924, Scientific Paper No. 491, pp. 487–540.

missions are usually comparable in length with the wavelength, the most common lengths being half and quarter of the wavelength. At these high frequencies it is important to supply the power in such a way as to suit the distribution of current and potential in the antenna. Fig. 18 shows the distribution of current and potential in an ungrounded half-wave antenna. If we wish to feed this antenna inductively from the transmission line we must do so at some point which is not a current node as shown in Fig. 18. Fig. 19 represents the current and voltage distribution in a grounded quarter-wave antenna. In this case current should be fed in inductively at the bottom. Voltage may be fed to the antinode of potential of the antenna. If we use voltage excitation of a

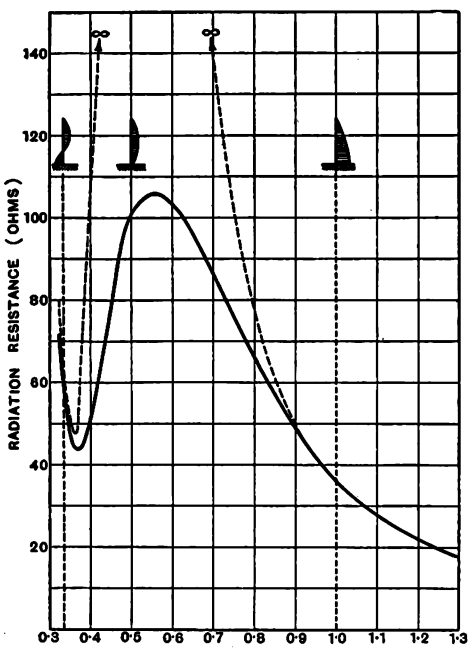


Fig. 20.—Radiation resistance of simple vertical antenna over perfect earth for wavelengths below the fundamental.

$\frac{\lambda}{2}$ ungrounded antenna we should do so at either end.

The radiation resistance of an antenna operating on medium and long wavelengths is given approximately by the expression

$$R_a = 40\pi^2\left(\frac{l}{\lambda}\right)^2 \text{ ohms,}$$

where l is the length of the antenna. This relation is only very nearly true when the distribution of current in the aerial is linear, that is, when the amplitude of current at any point is proportional to its distance from the free end of the aerial. This condition is only satisfied when the length of the aerial is small compared with the wavelength. Short-wave antennæ are not small compared with the wavelength and we can no longer use the usual formula for radiation resistance given above. Ballantine* has computed the radiation resistance of an antenna for wavelengths less than the fundamental, and Fig. 20 is taken from his paper. It will at once be noticed that the radiation resistance of antenna used on short waves is usually much greater than that on longer waves. This increase in radiation efficiency of the aerial partly explains the apparently phenomenal distances sometimes covered by the waves with low input powers. With the transmitter described above and shown in Fig. 17 we can obtain 0.50 ampere in a half-wave antenna at 7 metres. The radiation resistance of this antenna, as seen from Fig. 20, is approximately 100 ohms. Thus the aerial output is a little over 25 watts. The input to the transmitter is of the order of 300 watts so that the overall efficiency is very small, but we have not yet endeavoured to increase it as the output is ample for our present purpose, viz., the measurement of attenuation along the ground near the aerial.

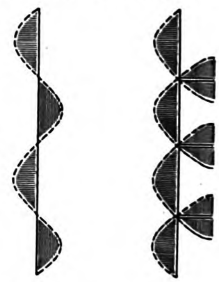


Fig. 21.—*Diagram showing the use of phasing coils in an aerial two wavelengths long to give maximum radiation in a horizontal plane.*

A glance at the distribution of current in an aerial working on wavelengths less than its fundamental will immediately indicate the possibility of radiating power in other than the horizontal direction. Each lobe of current may be considered roughly to act as a Hertzian oscillator at its centre with sign the same as that of the current in the

* S. Ballantine: "On the Radiation Resistance of a Simple Vertical Antenna at Wavelengths below the Fundamental," *Proc.* I.R.E., 1924, Vol. 12, pp. 823–832.

loop. In this way we see that successive loops of current in an aerial being of opposite sign interfere with one another's radiation in the horizontal direction. Therefore any antenna having an even number of current loops of opposite sign should give zero horizontal radiation. Franklin has overcome this effect of alternate loops interfering with one another by inserting in the aerial small phasing coils having low radiation resistance so as to cut out alternate loops. Fig. 21 shows how this would be done with an aerial whose length is equal to twice the wavelength of the current in it.

Ballantine* in another paper has calculated the radiation in the vertical plane for different angles to the horizontal for aerials of different length. Fig. 22 is copied from his paper. He has shown that for a given output maximum horizontal radiation is obtained when the ratio of wavelength to the fundamental of the aerial is 0.39.

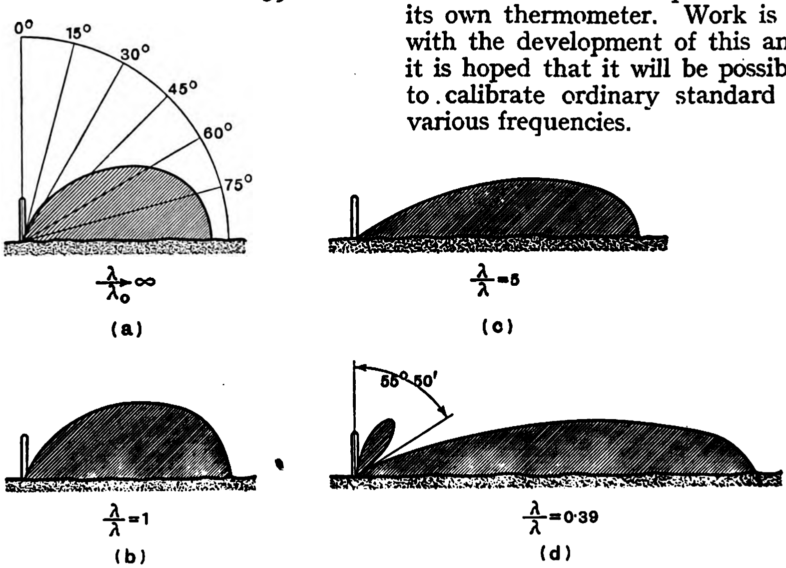


Fig. 22.—*Vertical antenna over perfect earth; diagrams representing intensity of the radiation at various angles of altitude for various wavelengths.*

(e) The Measurement of Current at Very High Frequencies.

The measurement of current at very high frequencies presents many difficulties. An ordinary radio-frequency ammeter has a certain capacity to its case which acts as a variable shunt resistance for the radio-frequency current, and unless the measuring element is properly screened it is difficult to correct for this effect. The tendency for current to travel on the surface of conductors also becomes very important at these high frequencies. In this way the calibration of an instrument which is correct at low frequencies may be false for the high frequencies used in short waves. Moullin† has developed a method for the measurement of current at very high frequencies, in which the attraction between two cylinders carrying the same current is measured. An ammeter of this type may be corrected for the errors mentioned above. In a paper to be published shortly Wilmotte describes another method which may be used. Essentially the method consists in passing the current through a column of mercury which indicates its temperature by acting as its own thermometer. Work is in progress with the development of this ammeter and it is hoped that it will be possible to use it to calibrate ordinary standard meters for various frequencies.

Part IV.

Development and Use of Receivers at Very Short Wavelengths.

In considering the design of receiving apparatus for use on very short wavelengths,

* S. Ballantine: "On the Optimum Transmitting Wavelength for a Vertical Antenna over Perfect Earth," *Proc. I.R.E.*, 1924, Vol. 12, pp. 833–839.

† E. B. Moullin: "An Ampere Meter for Measuring Alternating Current of Very High Frequency," *Proc. Roy. Soc.*, 1928, Vol. 121, pp. 41–71.

it is perhaps natural to review the various types of receiver which have been used with success on longer waves. The simplest type of receiver which has found widespread use on wavelengths from 100 metres downwards, is that of the single-valve detector type employing variable capacity retroaction. For the reception of modulated continuous waves this retroaction can be set critically to a point just below that at which the valve oscillates, while at a point just above the receiver is very sensitive for the reception of continuous waves on the autodyne principle. Since any valve circuit which will oscillate freely at the working frequency can be controlled by suitable adjustment of the retroaction, it is evident that any of the various arrangements described above can be made to serve for reception purposes by a suitable modification. Where additional sensitivity is required the possibilities of direct radio-frequency amplification immediately arise. Considerable experience with various types of radio-frequency amplifiers has shown that it is extremely difficult to obtain any appreciable amplification on frequencies above 20 megacycles per second (wavelengths below 15 metres). In certain receivers employing one or more stages of amplification at such frequencies, it is usually found that any amplification that is obtained is at the expense of the retroaction setting of the detector, and that if the H.F. stages are omitted this retroaction can be increased thus avoiding any overall loss in sensitivity. As a means of obtaining increased sensitivity with the aid of greater retroaction the super-regenerative type of circuit has been used by some investigators. The advantage of this circuit arrangement would appear to lie in the possibility of using more retroaction, the valve being prevented from dropping into oscillation by the quenching action of the supersonic oscillation at a lower frequency. The authors have so far, however, had no experience of this type of receiver.

For the greatest sensitivity in short-wave reception, the supersonic heterodyne would appear to offer great possibilities, and it is perhaps somewhat surprising to find that little or no work on the adaptation of this type of receiver to wavelengths below 10 metres has so far been published. At the present stage of the technique of amplification, it is a comparatively simple matter to obtain considerable voltage amplification at a moderate intermediate frequency of the order of 100 kilocycles per second. For the conversion of such an intermediate frequency amplifier to a short-wave receiver, it is necessary merely to precede it with a frequency-changing unit, which generates oscillations at the original very high frequency to heterodyne those due to the incoming signals. By the substitution of different frequency-changing units, it would appear possible to extend the range of the receiver down to the shortest wavelengths at which the receiving valves can be made to oscillate. Experimental work on these lines is being conducted, and although certain difficulties have been encountered in extending the wavelength range below about 7 metres, it is not considered that these are insuperable. The method possesses advantages in the possibility of employing two or more intermediate frequencies where the utmost sensitivity is required compatible with stability. This portion of the research work is, however, still in progress and a detailed description of it will be given in a later communication. For the present the objects of the authors are served by adopting the simplest type of receiver available at the moment in order to proceed with preliminary experiments on the propagation of very short waves.

For these receivers the single-valve retroactive detector has been employed using one of the two circuits shown in Figs. 6 and 7. Since oscillations can be obtained with such arrangements down to wavelengths below 3 metres, it has not been considered necessary to adopt the somewhat more complicated two-valve arrangements. Using the centre-tapped inductance coil in the circuit shown in Fig. 6, an open aerial can be coupled through a variable condenser to one end of the coil. If a definite earth connection is employed it is preferable that this should be to the centre of the coil, *i.e.*, the negative end of the filament. If, on the other hand, an insulated counterpoise system is used, this may be connected to the other end of the coil by a variable condenser in the same manner as the aerial. The complete circuit diagram of such a receiver is shown in Fig. 23. The salient point to observe is that in this circuit

the two ends of the inductance coil are at high alternating potential, and the aerial and counterpoise connected thereto should also be arranged to provide potential variations at these points. It is, therefore, necessary to ensure that the length of the aerial is not an odd multiple of a quarter of the wavelength since this would provide a potential node at the connection to the receiver. The search for optimum conditions with this type of receiver involves the adjustment of the length of aerial and of all the controls of aerial coupling, retroaction and tuning: in particular the correct adjustment of aerial coupling is important since if this is too great, the radiation resistance of the aerial will prevent the detector valve from oscillating, whereas if it is too small, a loss in sensitivity will result. A certain amount of experimental work was carried out on this type of receiver with satisfactory results, but for any sort of measurement work it is desirable to reduce the number of variables in the apparatus itself.

It was, therefore, decided to replace the receiving antenna by a closed loop and to mount this directly on the screened box containing all the receiving apparatus. In this way everything except the pick-up loop can be efficiently screened, a great advantage for many signal intensity and direction-finding measurements. Since for wavelengths below 10 metres the area-turns of the receiving loop will be comparatively small

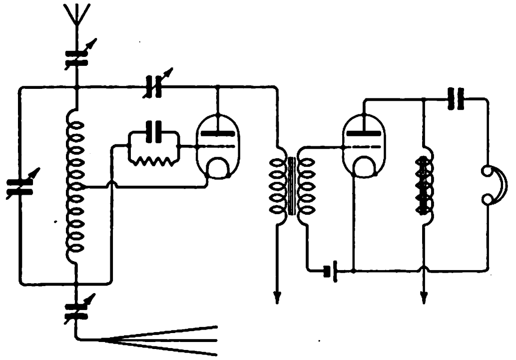


Fig. 23.—*Schematic circuit diagram of two-valve short wave receiver using centre-tapped input coil capacity-coupled to aerial and counterpoise.*

it will usually be desirable to make this of the single-turn type. In order to avoid the central tapping at the top of the coil the

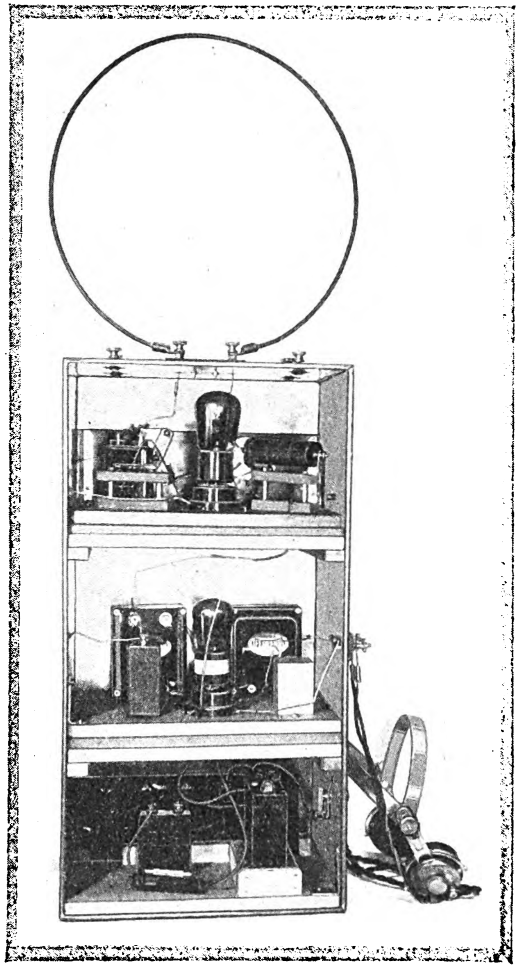


Fig. 24.—*Photograph of loop receiver using the circuit shown in Fig. 25. Wavelength range 4 to 10 metres.*

circuit arrangement shown in Fig. 7 was adopted for the detector valve. The tuning adjustment is effected by two variable condensers in series, the tapping to the filament being taken from their common connection. A photograph of a complete receiver built on these lines is shown as Fig. 24, while the diagram of connections and dimensions of the principal components are given in Fig. 25. In order to make the whole receiver as symmetrical as possible about the central axis of the loop, and also to shorten the lengths of the wiring to the first stage, the apparatus is arranged in three tiers as indicated in the photograph. The receiving

loop is held rigidly to the top of the box by its terminals, to the underside of which is connected the tuning condenser. The controls for this and the retroaction condensers are taken out through the back of the box, and sockets are provided for interchangeable grid leaks and choke coils. A single audio-frequency amplifying stage is mounted on the middle platform, while the necessary filament and anode batteries are placed at the bottom of the box. The output terminals for telephones are placed as a shunt across an audio-frequency choke in the anode circuit of the second valve; by this means the telephone leads and hence the observer are maintained at the screen potential, thus avoiding certain difficulties due to capacity changes. In considering the possible receiving range of this apparatus it may be mentioned that a loop of 12 inches diameter has an inductance of less than one microhenry, and requires only 18$\mu\mu$F. of capacity to tune it to a wavelength of 7 metres.

Using single-turn loops constructed of ¼in. diameter copper tube, the following wavelength ranges could be covered with a tuning condenser of which the minimum and maximum capacities were 2 and 24$\mu\mu$F. respectively.

Diameter of Loop.	Wavelength Range.
Inches.	Metres.
5	4.8— 6.9
8	5.5— 8.8
10	6.2— 9.5
12	6.7—10.8

capacity between the coil terminals and the effect of various components upon this capacity. The measurements were made by a substitution method using a standard variable air condenser and a wavelength of about 17 metres. With both tuning and retroaction condensers set to their minimum positions, the capacity between the coil terminals with the first valve in its socket was 9 and 12$\mu\mu$F. with the filament current off and on respectively. To this amount the base of the valve contributed 1$\mu\mu$F., while the capacity of the valve itself, *i.e.*, between its grid and anode was about 1.5$\mu\mu$F., leaving about 7.5$\mu\mu$F. to be attributed to the wiring connections and their capacity to the screened box. The alteration of the retroaction condenser to its maximum position increased the capacity between the coil terminals by 5$\mu\mu$F. The substitution of various grid leaks and choke coils in the detector valve circuit made no appreciable alteration to this capacity. It will thus be seen that the minimum capacity obtainable is limited by the capacity of the valve and its connections, and little reduction can be obtained in its value by omitting the valve holder or using a tuning condenser with a still lower minimum capacity than that at present in use (2$\mu\mu$F.). The chief disadvantage of this limitation is that it restricts the range of wavelengths which it is possible to cover with any one loop, but the above table indicates that there is no difficulty in making the receiver operate at wavelengths down to less than 5 metres. When it is desired to proceed to still shorter wavelengths, it is

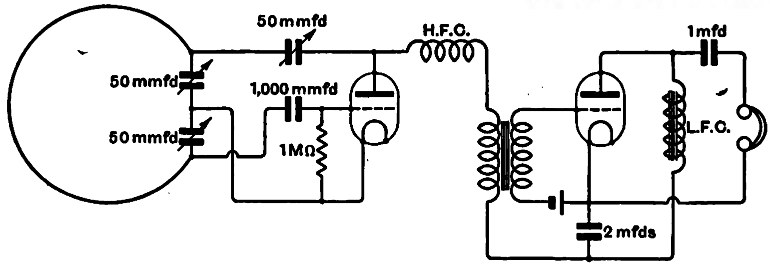


Fig. 25.—*Schematic circuit diagram of two-valve short wave loop receiver for field strength measurements and direction finding. Wavelength range 4 to 10 metres.*

In order to ascertain the possibility of reducing the minimum wavelength by a reduction in the stray capacity of the first stage, some measurements were made of the

an advantage to remove the stray capacity due to the screened box. In this way the same receiver has been made to operate at a wavelength of 2.9 metres.

Wave-meters.

As a general source of radio-frequency oscillations for measurement purposes, the type of valve wave-meter previously described by F. M. Colebrook* is very convenient. One of these models has been constructed covering a total wavelength range of from 4.7 to 100 metres with 5 plug-in coils. The construction of a slightly modified design to cover shorter wavelengths is in progress, but by using harmonics it is possible to get as low as 2.5 metres with the existing model.

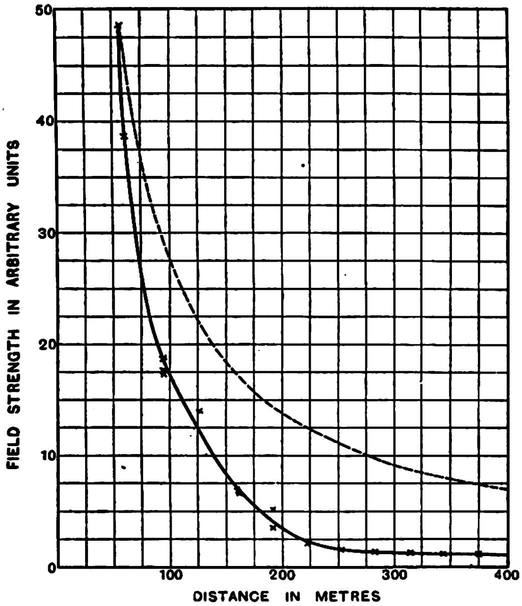


Fig. 26.—*Attenuation curve for wavelength of 8 metres.*

For making measurements upon a transmitter, it is convenient to have an absorption type of wave-meter, and one of these has been constructed with four interchangeable coils and a moderately good variable air condenser having a maximum capacity of 50$\mu\mu$F. As indicator a crystal detector and small pointer galvanometer are used in an aperiodic loop circuit coupled to the resonant circuit. The wavelength range of this instrument is 3.5 to 25 metres.

For laboratory work probably the most accurate method of measuring wavelengths is by means of a pair of Lecher wires. Such a system has been used for most of the development work described in Part III. above. Two copper wires are stretched horizontally three inches apart at a height of about nine feet and two or three feet away from all neighbouring objects. At one end these wires are short-circuited and form a means of coupling to the oscillating source. The positions of current and potential nodes are then located by means of a bridging link containing a vacuum thermo junction and micro-ammeter. The distance between successive nodes of either type is one-half of the wavelength. Where the length of the wires is greater than the wavelength, this method of measurement is convenient and accurate, but for field work and portable use one of the types of meter described above is much more convenient.

* F. M. Colebrook: *E.W. & W.E.*, 1927, Vol. 4, p. 722.

Some Typical Experiments at Short Wavelengths.

It will have been gathered from the early part of this paper that the object of the work described was to develop the necessary apparatus by means of which certain experiments on the propagation of waves might be carried out. In attempting to make measurements on the very short wavelengths in question the experimenter is soon impressed with the need for adopting much more than the ordinary precautions usually associated with radio measurements at lower frequencies. The worker must continually remember that the waves instead of being much longer are now much shorter than the dimensions of such objects as trees and houses, and that therefore these objects present moderately effective reflecting surfaces having dimensions of at least several wavelengths. Any experiments on propagation must, therefore, be carried out with great caution and every effort made to exclude the effect of neighbouring objects.

In order to obtain reasonable conditions in this respect the short-wave transmitter illustrated in Fig. 17 was erected at the Radio Research Station, Slough, on a site which, while hemmed in by trees on one side, provided a clear run across a field for a distance of about 600 yards in other directions.

The results of a typical set of relative field-strength measurements made at various distances across this field on a wavelength

of 8 metres are plotted in Fig. 26. For reference purposes the attenuation curve over a perfect conductor on the assumption of an inverse distance law is given on the same

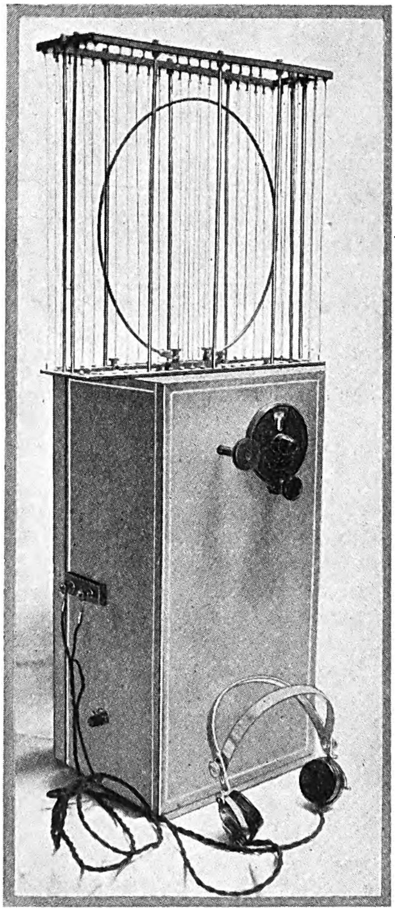


Fig. 27.—*Short wave loop receiver fitted with an electric screen for field strength and direction-finding measurements on wavelengths* 4 *to* 10 *metres.*

diagram, and it is seen from the two curves that the decrease of field-strength with distance is very great on such short wave-lengths.

The receiver with which the above measurements were taken, and which was illustrated in Fig. 24, can be used as a tolerably good direction-finder if it is mounted on a suitable turntable with a graduated scale. When used for aural reception in this manner bearings can be obtained fairly comfortably using modulated waves at the source on a wavelength of from 7 to 10 metres. If unmodulated waves are employed with autodyne reception it is difficult, to retain constancy of the audible note as the set is rotated, but with care and patience it is still possible to obtain bearings. In either case the signal minima on the set are considerably improved in quality and are made much more symmetrical by fitting an open vertical wire screen around the receiving loop, in accordance with the practice on longer waves first established by R. H. Barfield.* A photograph of the short-wave direction-finder fitted with such a screen is shown in Fig. 27 and with this instrument bearings can be obtained with care to an accuracy of 2° or 3°. These are, of course, subject to serious error under many conditions due to reflections from neighbouring objects. An attempt has been made to measure the polar diagrams of this direction-finder and the result of the observations

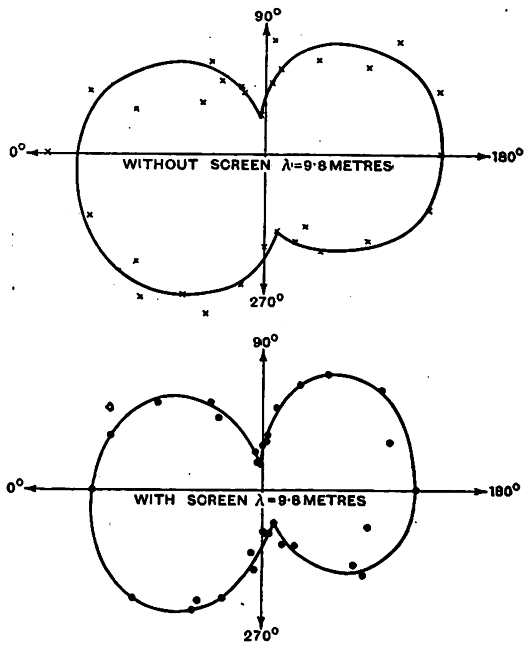


Fig. 28.—*Polar reception curves of the loop receiver shown in Figs.* 24 *and* 27.

made with and without the electric screen in position are shown in Fig. 28. The results

* R. H. Barfield: "Some Experiments on the Screening of Radio Receiving Apparatus," *Journal I.E.E.* 1924, Vol. 62, pp. 249-264.

are not of a high order of accuracy due, amongst other things, to the effect of the presence of the observers, but the polar curves show the kind of minima which it is possible to obtain, and indicate that the development of a reasonably accurate direction-finder for use on these very short wavelengths is certainly within the realms of possibility. These few results also serve to show that no new fundamental principles arise in the science and practice of radio work on very short wavelengths, but the technique of the subject merely requires the experimenter to adjust his ideas and experiences to conform to the smaller dimensions of the waves with which he is working.

The work described in this paper was carried out as part of the programme of the Radio Research Board, and the authors are indebted to the Department of Scientific and Industrial Research for granting permission for publication.

The authors also wish to acknowledge the assistance rendered by Mr. A. C. Haxton in the experimental work.

ERRATUM.—In the first instalment of this article in last month's issue the diagrams of Figs. 4 *and* 5 *on page* 537 *should have been transposed.*

Note on the Apparent Demodulation of a Weak Station by a Stronger One.

By S. Butterworth, M.Sc.

IN the issue of *E.W. & W.E.* for June, 1928, Dr. R. T. Beatty discusses the nature of the rectified signal when two stations of slightly differing wave lengths are being received simultaneously. He points out that the carrier wave of the stronger station exerts a powerful demodulating effect on the signal from the weaker station, and thus explains the well-known fact that two stations are acoustically separable in cases where mere inspection of the resonance characteristic of the receiver would lead one to expect very powerful interference.

As this effect is of fundamental importance in the problem of selectivity, it is important that we should obtain quantitative notions as to its magnitude, and Dr. Beatty has given an elementary treatment leading to a numerical estimate of the amount of demodulation in simple cases.

In the case of perfect rectification, this treatment leads to a very surprising result, namely, that the carrier wave of the stronger station *completely* demodulates the weaker station, so that, if the conclusion is correct, the effect of varying tuning should be to cause a sudden change over of the received signal from one station to the other at the point where the voltages impressed on the rectifier are equal. This effect does not, of course, occur, and in order to account for the observed gradual transition, Dr. Beatty makes use of the curvature of the rectification characteristic. In the present note, however, it is shown that there is no need to do this as, owing to over simplification in order to avoid mathematical complexity, the amount of the demodulation with perfect rectification has been overestimated.

Take first the case of two unmodulated carrier waves having pulsatances* ω and $\omega + p$. The difference in pulsatance p is supposed small compared with ω, but it is still supersonic, so that there is no audible heterodyning. Let the strengths of the signals to be rectified be X and Y, so that the voltage received by the detector is of the form

$$v = X \cos \omega t + Y \cos (\omega + p)t \quad .. \quad (1)$$

This may be written

$$v = (X + Y \cos pt) \cos \omega t - Y \sin pt \sin \omega t \quad (2)$$

or, if we put

$$\left. \begin{aligned} X + Y \cos pt &= R \cos \psi \\ Y \sin pt &= R \sin \psi \end{aligned} \right\} \quad .. \quad (3)$$

* The pulsatance is the frequency multiplied by 2π.

that is

$$\left.\begin{aligned} R^2 &= X^2 + Y^2 + 2XY \cos pt \\ \tan\psi &= Y \sin pt/(X + Y \cos pt) \end{aligned}\right\} \quad .. \quad (4)$$

we get

$$v = R \cos(\omega t + \psi) \quad .. \quad (5)$$

Since p is small compared with ω, there are many cycles of the carrier wave for very small changes in R and ψ, so that R, when plotted against time, will give the outline of the envelope representing the succession of carrier wave peaks. With a perfect rectifier, that is, one which removes the negative pulses but leaves the positive pulses undistorted, the mean wave for many cycles of ω but few of p is $2R/\pi$, and this is what would be recorded after rectification by a linear detecting instrument capable of following variations of pulsatance p, but too sluggish to record variations of pulsatance ω.

If, however, the instrument is too sluggish to follow the supersonic ripple, it will only record the mean value of R for many cycles of pulsatance p. If this is R_m, we have

$$\pi R_m = \int_0^\pi (X^2 + Y^2 + 2XY \cos\theta)^{\frac{1}{2}} d\theta$$

$$= 2(X + Y)\int_0^{\pi/2} (1 - k^2 \sin^2\psi)^{\frac{1}{2}} d\psi$$

in which

$$\psi = \theta/2, \text{ and } k^2 = 4XY/(X + Y)^2 \quad (6)$$

The latter integral is well known as the complete elliptic integral of the second kind to modulus k, and is usually denoted by $E(k)$, so that we may write

$$R_m = 2(X + Y)\, E(k)/\pi \quad .. \quad (7)$$

The equation shows that the mean recorded current will vary both with X and Y. This conclusion differs from that obtained by Dr. Beatty, who found that the mean recorded current was proportional to the strength of the stronger signal only. The difference in the two results is due to the fact that in equation (2) Dr. Beatty ignored the term $Y \sin pt \sin \omega t$ and thus obtained an erroneous form for the supersonic envelope.

Now let one of the stations (say X) be modulated at audio frequency and suppose the detecting instrument capable of following these variations. At any instant suppose x is the variation superposed on the steady value X and let x/X be small. Then

$$R_m \text{ is replaced by } R_m + x\frac{dR_m}{dX} \quad .. \quad (8)$$

and by differentiation of (7) we find

$$\frac{dR_m}{dX} = \{(1 + Y/X)\, E(k) + (1 - Y/X)\, K(k)\}/\pi \quad .. \quad (9)$$

Here $K(k)$ is the complete elliptic integral of the first kind to modulus k, viz. :—

$$K(k) = \int_0^{\pi/2} d\psi/(1 - k^2 \sin^2\psi)^{\frac{1}{2}}$$

Using Tables of elliptic integrals, the following values of $\frac{dR_m}{dX}$ have been computed, in which equal intervals of Y/X have been taken when Y is less than X and equal intervals of X/Y when Y is greater than X.

VALUES OF $\frac{dR_m}{dX}$

X greater than Y.		X less than Y.	
Y/X		X/Y	
0.0	1.000	0.0	0.000
0.1	0.998	0.1	0.052
0.2	0.990	0.2	0.100
0.3	0.977	0.3	0.153
0.4	0.959	0.4	0.205
0.5	0.934	0.5	0.256
0.6	0.902	0.6	0.314
0.7	0.862	0.7	0.380
0.8	0.815	0.8	0.438
0.9	0.749	0.9	0.524
1.0	0.637	1.0	0.637

It is seen from the Table that when the disturbing station (Y) is absent, $\frac{dR_m}{dX}$ is unity, so that in all cases $\frac{dR_m}{dX}$ is a direct measure of the demodulation produced on X by the carrier wave of Y, and thus $\frac{dR_m}{dX}$ is the demodulation factor.

The demodulation factor giving the demodulation produced on Y by the carrier wave of X is similarly $\frac{dR_m}{dY}$. The values of $\frac{dR_m}{dY}$ are also given by the above Table, provided that we interchange X and Y at the top of the first and third columns. This is true because of the symmetrical way in which X and Y appear in equation (4).

Further, if we are considering the two

stations simultaneously, the second column will give the demodulation of X by Y and the fourth column the demodulation of Y by X for values of Y/X given by the first column in both cases.

Using this interpretation, if we take the ratios of the demodulation factors $\frac{dR_m}{dY}$ and $\frac{dR_m}{dX}$ for corresponding values of Y/X and multiply by Y/X we obtain the ratios of the received acoustic signals. This yields the following Table:

Carrier Wave Ratio.	Acoustic Ratio.	Carrier Wave Ratio.	Acoustic Ratio.
0.1	0.0052	0.6	0.209
0.2	0.0202	0.7	0.308
0.3	0.0470	0.8	0.430
0.4	0.0656	0.9	0.630
0.5	0.137	1.0	1.000

The carrier wave ratio is, of course, that which would be deduced from the resonance characteristic of the receiver, but it is the acoustic ratio which is important in estimating the selectivity. It must be emphasised that the above Tables only hold for perfect rectifiers. The curvature of the rectification characteristic will tend to increase the above acoustic ratios. In fact, when the rectification follows the square law, as is practically the case for weak signals, the demodulating effect completely disappears and in this case the acoustic ratio is the square of the carrier wave ratio. These squares are larger than the acoustic ratios given in the last Table, being nearly twice as large when the carrier wave ratio is small. This means that if we push up the H.F. amplification until there is a considerable swing of voltage across the grid of the detector valve, there will be a gain in selectivity which may be of the order of nearly 2 to 1 as compared with what would be got if detection occurred immediately and the necessary volume was obtained by L.F. amplification. This is altogether apart from the increased selectivity obtained by the resonant circuits of the H.F. amplifier and thus we are given an additional argument in favour of adequate H.F. amplification.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Moving Coil Speakers.

To the Editor, E.W. & W.E.

SIR,—In a letter in the August number, Dr. McLachlan has raised several points in connection with my paper on Moving-coil speakers in the July number.

In the first place, if he thinks I have not given him sufficient credit for his pioneer work on the M.C. speaker, I can only apologise; I do not think much harm has been done, for anyone taking an interest in the subject must be perfectly well aware of his work, and the addition of a footnote would have conveyed nothing new; in any case, if he will refer to p. 364 (top of second column) he will see that I speak of "the design originated by Dr. McLachlan."

I have no references by me, but I have always been under the impression that Rayleigh did the mathematics of the plane diaphragm in the eighties, and that the first "M.C. speaker" (with a wooden board for a diaphragm) was made by Lodge in the nineties; since when nothing further was done until Dr. McLachlan designed the first instrument at all resembling what we now call a "M.C. speaker" for the Science Museum. Reference to the files of *E.W. & W.E.* and of *The Wireless World* might settle this definitely.

It is very unfortunate that Dr. McLachlan's paper suffered so much delay before being submitted for publication; had it appeared 18 months earlier it would have saved me a lot of work. I must, however, take exception to his statement that I have "*repeated*" part of his paper; it would be equally correct, or rather incorrect, to say that he had "repeated" part of mine: we have both covered the same ground, to a large extent, but to say that either "repeated" the other is to suggest that one had previous knowledge of the other's work, for it is impossible to "repeat" what has not been previously heard or published. The acrimony engendered by disputes on priority is usually proportional to the square of their lack of interest or importance to anyone but the protagonists; it is therefore fortunate that in the present case no such question of "priority" can arise, as the interval between the dates of publication is too small (I understand that the booksellers received the June supplement to *Phil. Mag.* and the July *E.W. & W.E.* on the same day), and of course even an interval of a month or two would not be sufficient for the preparation and printing of either

paper. The truth of the matter is, of course, that neither knew of the other paper until it was seen in print, internal evidence of which is found in the fact that each paper contains matter not found in the other. For example, Dr. McLachlan goes far more fully into the transient question; but thanks to the kindness of Professor Watson, my paper shows that the function Dr. McLachlan, following Rayleigh's original notation, calls $K_1(z)$ is connected with a known and tabulated function (Struve's function) in fact, as stated on p. 359 of my paper,

$$K_1(z) \equiv z\mathbf{H}_1(z),$$

a fact which, had it been known to him, would have saved Dr. McLachlan much tedious summing of series.

I am, of course, perfectly well aware of Dr. McLachlan's earlier articles and his book; with the latter in particular, I was disappointed on account of its lack of information as to how various quantities such as motional (or radiation) resistance and motional capacity were to be obtained for any particular coil other than that described (with about 1,000 turns). While a number of vector diagrams were given, there was no indication of the accuracy of approximations such as the assumption that the motional capacity is constant. It is possible that the equation for the value of the motional capacity $\left(\text{in my notation } K = \frac{m}{y^2B^2}\right)$ may have been published previously in an issue of *The Wireless World* earlier than my current file contains, but I certainly cannot find it in my copy (1st edn.) of "Loudspeakers" (of course it appears, with different notation, in the *Phil. Mag*. paper).

Possibly Dr. McLachlan thinks in terms of vector diagrams, while I think rather in terms of differential equations; but whatever the cause, I must own I found the explanations in "Loudspeakers" very hard to follow; it was never stated that they were more than empirical approximations for the particular speaker described, justified by the fact that they "Worked," and it was not until I had worked it out for myself from the equations that I realised that they had a theoretical basis, and were accurate to a high degree of approximation for *any* M.C speaker.

I agree that the expression "adherent air" is misleading, "accession to inertia" is better, I did not refer to Dr. McLachlan's introduction of the question in 1927, as it was actually introduced by Rayleigh in 1887, to which I refer in the text; the footnote referring to *E.W. & W.E.* editorials of 1929 was given, as stated therein, because it included a recent bibliography (thereby saving a half-page of references) and a lucid explanation of the reasons why an accession to inertia is to be expected.

I should be most interested if Dr. McLachlan could give us an explanation of a method, even if only an approximate one, for predicting the (static) inductance of a moving-coil in place in the pot-magnet. I believe there is a method used by dynamo designers which could be adapted.

C. R. Cosens.

Definition of Selectivity.

To the Editor, E.W. & W.E.

Sir,—I am much indebted to Mr. Biedermann for his useful comments on my proposal for the specification of selectivity (see *E.W. & W.E* for August, 1929).

My proposal is, briefly, that given an impedance Z, which is a function of frequency $(\omega/2\pi)$, resonance shall be defined by

$$\frac{\partial Z}{\partial \omega_r} = 0$$

and selectivity by

$$\omega\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial \omega_r^2}\right|}$$

Mr. Biedermann traces the derivation of this formula and shows that it is based on the coefficient of $\left(\frac{\delta\omega}{\omega_r}\right)^2$ in the expansion of $Z^2(\omega + \delta\omega)$ in terms of $Z^2(\omega)$ and $\delta\omega$. He then questions the validity of neglecting the remaining terms of the series. This really amounts to saying that the value of

$$\frac{\partial Z^2}{Z_r^2}\bigg/\left(\frac{\delta\omega}{\omega_r}\right)^2$$

may depend on $\delta\omega$. It certainly will in every case, and that is why I have proposed the above formula, which is independent of $\delta\omega$, since

$$\omega_r\sqrt{\frac{1}{Z_r}\left|\frac{\partial^2 Z}{\partial \omega_r}\right|^2} = \underset{\delta\omega \to 0}{lt}\sqrt{\frac{\delta(Z^2)}{Z_r^2}\bigg/\frac{\delta\omega}{\omega_r}}$$

In other words, I have introduced the limiting condition $\delta\omega \to 0$, in which case, assuming the convergency of the series for $Z^2(\omega + \delta\omega)$, all the terms of the series vanish except that on which the proposed definition of selectivity is based.

Mr. Biedermann's second comment is largely a matter of personal opinion. The question is, should the definition of selectivity be based on a proportional change in frequency (*cf.* resolving power in optics) or on some arbitrary agreed absolute change in frequency. I agree with Mr. Biedermann that the latter basis might have advantages from a practical and technical point of view. On the other hand, the former leads to a definition which is quite free from any arbitrary element and is thus more satisfactory from a logical and scientific point of view.

F. M. Colebrook.

Teddington.

Abstracts and References.

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PROPAGATION OF WAVES.

SUR LES ÉCHOS RETARDÉS (Retarded Echoes).—C. Störmer. (*Comptes Rendus*, 26th Aug., 1929, Vol. 189, pp. 365–368.)

The situation is most favourable to the occurrence of these echoes, according to the writer's "toroidal space" theory, when the line earth-sun makes the smallest angle with the magnetic equatorial plane of the earth, *i.e.*, the plane passing through the earth's centre and normal to its magnetic axis. The writer gives a list of the values of the angle, at the dates of the echoes observed in Oct. 1928, Feb. 1929, and also of the most recent echoes in April, 1929. Apart from one day (23rd April) the angles were of the order of 0.1 to 6 deg., whereas for the transmissions (67 in number) when no echoes were heard, the angles varied from -31 and 33 deg. The Indo-China echoes mentioned in Oct. Abstracts occurred with angles about 5.7 to 9.6 deg. The anomalous result on 23rd April occurred with an angle of about 24 deg. Previous echoes had been heard on 4th, 9th and 11th April (angle -0.2 to 2.9 deg.) after which there was a gap till the 23rd.

The writer points out that while his original note of 5th Nov., 1928, deals particularly with reflection at the surface of the toroidal space, there are other possibilities of reflecting surfaces; in particular he mentions the corpuscular ring outside the moon's orbit, whose existence he was led to suggest in 1910 in his explanation of the aurora borealis.

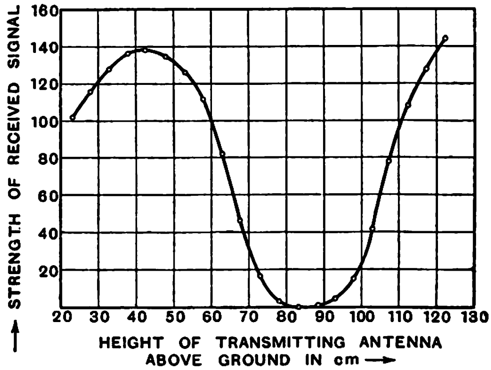
He refers to Pedersen's recent memoir (October Abstracts, p. 565) to the Danish Academy of Sciences in which that worker goes deeply into the various theories of long time echoes and adopts that of the writer; indicating as possible, moreover, echoes from corpuscular currents still more distant—a prophecy which is apparently confirmed by certain observations of Hals', quoted in Pedersen's paper, of echoes arriving 3 or 4 minutes after the signal.

The writer urges the need for international collaboration in studying the corpuscular currents of cosmic space by this new method; to see whether the usual theory of such currents can explain completely the echo phenomena, or whether it must be modified—*e.g.*, by taking into account the electromagnetic mutual actions of the corpuscles in motion: and to trace, by observations continued over several days at the right time, the great corpuscular beams which must emanate from the sun and (by the movements of sun and earth) may approach the earth little by little and finally cause magnetic storms and polar auroras. "The study of the approach of these currents and of their deformations by the earth's magnetism would be of the highest scientific interest."

MESSUNG DES LEITVERMÖGENS DER ERDE FÜR KURZE ELEKTRISCHE WELLEN (Measurement of the Conductivity of the Earth for [Very] Short Electric Waves).—M. J. O. Strutt. (*Naturwiss.*, 13th Sept., 1929, Vol. 17, pp. 727–728.)

A radiation-measurement method for obtaining the earth conductivity has been developed in connection with the writer's theoretical work dealt with in June Abstracts, p. 329. The receiving apparatus was suspended at a height of about 15 m. and a horizontal distance of about 13 m. from the transmitter. The latter (with horizontal antenna) was moved up and down so that the directly-received wave, interfering with the reflected wave, produced variations in signal strength. From a curve of the signal strength as a function of the height of the transmitting antenna the complex reflection coefficient of the earth was calculated, and from this the conductivity.

The transmitter gave a 1.42 m. wave, 100 per cent. modulated at 435 p.p.s. The receiver had one valve detector with tuned L.F. (435 p.p.s.) amplification. The final stage was a valve voltmeter. Preliminary calibration and tests established that the received signal varied strictly linearly with the transmitted strength and that radiation and reception took place only at the antennæ themselves.



The curve shown was taken over stripped heath land. Immediately after the test, the specific resistance was measured with d.c. and with 500-cycle a.c.

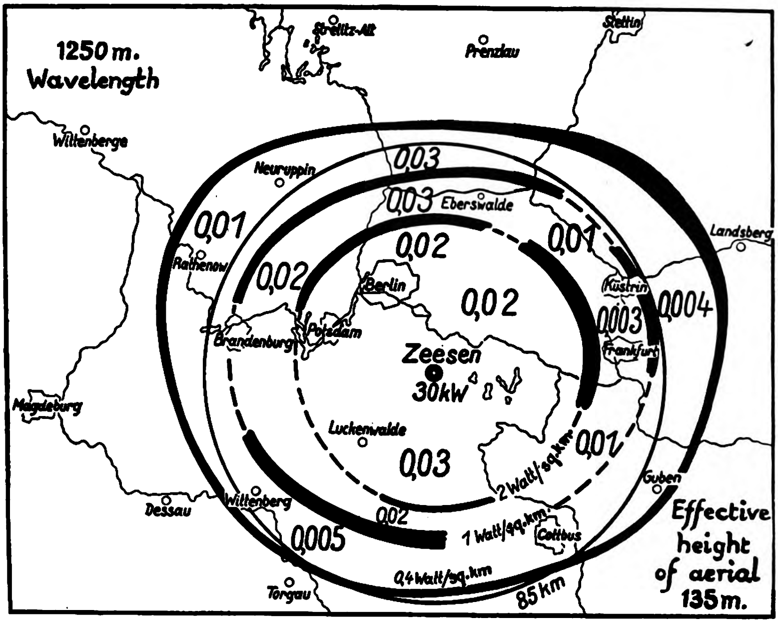
For the 1.42 m. wave, reckoning the refraction coefficient as $n^2 = e - \lambda k.6\sqrt{-1}$ (where e = dielec. const., k = const. of measuring system), the conductivity was more than 10^{-12} e.m.u. For d.c. and 500-cycle a.c. it was 0.89×10^{-13} and 1.15×10^{-13} e.m.u. respectively. Further results over different types of land and on different wavelengths are promised.

Further Note on the Ionization in the Upper Atmosphere.—J. C. Schelleng. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1313–1315.)

"A recent paper [Feb. Abstracts, pp. 98–99] by the present writer has brought from other workers in the field a considerable amount of discussion through the medium of personal letters. The author believes that the objections which were in this way raised have been shown not to be valid and that his correspondents now agree in this statement. However, it may be well to put on record certain considerations the omission of which for the sake of brevity caused difficulty." The writer then clarifies his proof that the fringe experiment and the group experiment give identical results, the identity being proved regardless of what the mechanism will eventually prove to be. "The proof is more general than one based on ray theory, and attention is particularly called to the fact that Fermat's principle of least time is not needed to prove the equivalence of the two methods," as it was in Appleton's proof (also referred to in February Abstracts, and anticipating that of the present writer). It is, however, called in here to explain the equivalence also of the third ("triangulation") method of Breit and Tuve.

Die Wellenausbreitung des Deutschlandsenders (The Wave Propagation of the "Deutschland" Transmitter).—F. Kiebitz. (*E.N.T.*, August, 1929, Vol. 6, pp. 303–306.)

An account of measurements made last Autumn at about 100 places at distances of 50–100 km. from the transmitter. The absorption by the ground was different in different directions. Measured by the logarithm of the decreased radiation over 1 kilometre, the absorption, moreover, was of the order of 0.01 at close quarters and only 0.001 at long range. General results are shown in the map given below.



It is suggested that the decrease of absorption with increasing distance may be due to the course of the Elbe and Oder rivers, while the large near values may be produced by the wooded and hilly districts to the N. and S. of Berlin respectively. On the other hand, the decrease with increasing distance may be due to a more fundamental effect—the absorption may be considered as affecting the lower part only of the wave-front, and this lower part forms a smaller and smaller fraction of the whole front as the distance increases. "In fact, according to the Huygens-Fresnel principle the space wave must partially compensate for the energy-current absorbed in the earth."

The Propagation of Low Power Short Waves in the 1,000-Kilometer Range.—K. Krüger and H. Plendl. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1296–1312.)

An English version of the paper dealt with at some length in June Abstracts, pp. 321–322.

Änderung der Empfangsfeldstärke über Land mit der Entfernung bei langen Wellen (Variation of Received Field Strengths with Distance, for Long Waves over Land.)—H. Fassbender. (*E.N.T.*, Aug., 1929, Vol. 6, p. 339.)

The earlier value found for the quantity a in the Austin-Cohen formula was 0.0015 over sea. Later measurements over land gave very varying results, most of which, however, could be explained by a change of a with the time of day. The writer

refers to tests between a transmitter in an aeroplane and an Anders field-strength measuring apparatus on the ground, to investigate the changes of α in short times on different wavelengths. Tests at the same hour on different days agreed sufficiently well, but tests over different routes gave differing pictures of the distribution of field strengths. For the route Berlin-Hanover, the value for α was 0.01 for a 300 m. wave and decreased down to 0.004 for a 2,000 m. wave.

An Investigation of Short Waves.—T. L. Eckersley. (*Journ. I.E.E.*, August, 1929, Vol. 67, pp. 992–1032.)

The full paper, with discussion, summaries of which were dealt with in June and July Abstracts, pp. 321 and 385.

Difference in Long Wave Propagation in England and America: Earth Conductivities?—S. W. Dean. (*See* Discussion of Smith-Rose's paper, under "Directional Wireless.")

The Problems Centering about the Measurement of Field Intensity.—S. W. Edwards and J. E. Brown. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1377–1384.)

A continuation of the work dealt with in 1928 Abstracts, V. 5, p. 690. The activities of the Radio Division of the U.S.A. Department of Commerce are described, and specimen Field Intensity Contour Maps are reproduced. *Cf.* Barfield, *E.W. & W.E.*, Jan., 1928, pp. 25–30; also Barfield and Munro, Feb. Abstracts, pp. 98 and 262.

The Attenuation of Wireless Waves over Land: Discussion.—R. H. Barfield: C. R. Englund. (*Journ. I.E.E.*, July, 1929, Vol. 67, p. 931.)

A communication from Englund regarding points in Barfield's 1927 paper (see 1928 Abstracts, page 285). He considers the use of the optical analogy in the case of a ground wave as not justified and as liable to lead to error, and quotes Sommerfeld's warning on the point. In his reply, Barfield justifies its use as leading, in a few lines, to a solution of the problem identical with that reached by Sommerfeld after a prolonged and extremely complicated analysis; although the proof is not rigid, it gives a ready means of arriving at the exact nature of the field of a ground wave at the earth's surface, and enables one to express in a simple and (he considers) a rigidly accurate way the amount of energy absorbed from such a wave by the earth's surface. It ought to be realised that the analogy is only valid for conditions at the surface or so near that it can be reasonably assumed that the fundamental boundary conditions of electromagnetic wave theory hold good.

Ions and Electrical Currents in the Upper Atmosphere.—E. O. Hulbert. (*See* under "Atmospherics.")

Observations of the Height of the Ozone in the Upper Atmosphere.—F. W. P. Götz and G. M. B. Dobson. (*Proc. Roy. Soc.*, 2nd Sept., 1929, Vol. 125 A, pp. 292–294.)

A continuation of a previous paper (Abstracts, 1928, Vol. 5, p. 517) on measurements over Arosa. Recent improved determination of the spectrograph constant has led to the adoption of a higher value for this. This means that the heights previously published should be increased by about 18 km., bringing the average height to about 50 km. The most important result of the work is the establishment of the fact that the average height is *not* lower when there is much ozone than when there is little; if anything, the reverse would appear to be more nearly true. This contradicts most of the hypotheses which might be put forward to explain the connection between the changes in the amount of ozone and the meteorological conditions in the lower atmosphere.

Thermal Diffusion at Low Temperatures.—T. L. Ibbs, K. E. Grew, and A. A. Hirst. (*Proc. Phys. Soc.*, 15th Aug., 1929, Vol. 41, Part 5, No. 230, pp. 456–475.)

Measurements were made with one side of the apparatus at about 15° C. and the other at temperatures down to about − 190° C.

Low Frequency Sound Waves and the Upper Atmosphere.—E. H. Gowan. (*Nature*, 21st Sept., 1929, Vol. 124, pp. 452–454.)

A survey of our present knowledge. British work with the hot wire microphone is mentioned briefly, further information being indicated in Whipple's summary (Feb. Abstracts, p. 100): German work with the self-contained, portable and cheaper "undograph" is treated more fully.

The Recombination of Ions and of Ions and Electrons in Gases: the Theory of Recombination of Gaseous Ions: Recombination of Free Electrons and Positive Ions.—L. C. Marshall; L. B. Loeb and L. C. Marshall; R. Seeliger. (*Phys. Review*, 1st Aug., 1929, Vol. 34, pp. 541 and 542—Abstracts only. *Physik. Zeitschr.*, 1st June, 1929, Vol. 30, No. 11, pp. 329–357: a Survey.)

Über den Durchgang von Ionen durch verdünnte Gase (The Passage of Ions through Rarefied Gases).—H. Kallmann and B. Rosen. (*Naturwiss.*, 6th Sept., 1929, Vol. 17, pp. 709–710.)

Results from various sources on the ionisation processes resulting from electron impact, investigated by the Aston mass-spectograph, have been contradictory. By this method the separation of primary and secondary processes is attempted by means of pressure variations in the gas under investigation. The writers' investigations, made from a different view-point, lead them to conclude that no consistent results can be obtained by the former method, since the pressure changes affect not only that part of the apparatus where the ions are formed but also the part where the ions traverse

the magnetic field, and here in an uncontrollable manner.

They have found that the ions in passing through this space are very strongly absorbed even at slight gas pressures, and to a different extent for different kinds of ion, so that the intensity ratio of the two sorts of ion is altered by absorption in a way which upsets any conclusions as to a secondary reaction in the ionising space. In their tests they kept the pressure constant in the ionising chamber and varied, under control, that in the magnetic field part. It was found that nitrogen atomic ions and molecular ions were differently absorbed in nitrogen, the latter more than the former; the same difference occurs for oxygen ions in oxygen, though to a less extent. On the other hand, with these same ions in neon the difference in absorption diminishes to vanishing point. These results may be explained by supposing that in a neutral gas the ions exchange their charges with the neutral molecules, but only when the ionisation potential of the ion system agrees as nearly as possible with that of the neutral gas: thus N_2+ is strongly absorbed in nitrogen and argon, O_2+ in oxygen, and $A+$ in argon; whereas $N+$ shows little absorption in nitrogen, $O+$ little in oxygen, and N_2+ and $A+$ little in neon. This exchange of charge takes place without appreciable decrease in a velocity range from 50 to 1,000 v.

TESTS OF SIGNIFICANCE IN HARMONIC ANALYSIS.—R. A. Fisher. (*Proc. Roy. Soc.*, 1st August, 1929, Vol. 125 A, pp. 54–59.)

ZUR QUANTENDYNAMIK DER WELLENFELDER (On the Quantum Dynamics of Wave Fields).—W. Heisenberg and W. Pauli. (*Zeitschr. f. Phys.*, 8th July, 1929, Vol. 56, No. 1/2, pp. 1–61.)

"In the Quantum Theory it has not yet been possible to connect together, without contradictions, mechanical and electrodynamical properties, electro- and magneto-statical interactions on the one hand and the interactions involved in radiation on the other hand. In particular it has not been possible to obtain a correct view of the finite velocity of propagation of electromagnetic action. It is the object of the present work to fill in this gap."

THE EFFECT OF A TRANSVERSE MAGNETIC FIELD ON THE PROPAGATION OF LIGHT IN VACUO.—W. H. Watson. (*Proc. Roy. Soc.*, 2nd Sept., 1929, Vol. 125 A, pp. 345–351.)

Since the photon is assumed to be electromagnetic in origin, and can produce electromagnetic effects, it is necessary to assign to it some electromagnetic character. The simplest particle properties which one can postulate are those of electric moment and magnetic moment—free electric charge being excluded by the fact that light is not deflected in a uniform electric or magnetic field. The paper deals with an investigation to detect, if possible, the existence of the magnetic moment of a photon. The result was negative; that is, the magnetic moment—if it exists—is less than 1.4×10^{-22} e.m.u.; i.e. it is less than 0.015 of a Bohr magneton. The alteration in the refractive index of vacuum produced by a magnetic field perpendicular to the direction of light propagation does not exceed 4×10^{-11} per gauss. The influence of a magnetic field component of 2,500 gauss *parallel* to the direction of propagation was also tested, with negative results. It is pointed out that the experiment proves conclusively that the Zeeman effect is determined completely by the emitting atom in the field, and that no effect (within the limits mentioned in the paper) is contributed by the propagation of the light from a region where the magnetic field is strong to a place where it is weak.

ÜBER EINE MÖGLICHE INTERPRETATION DES ELEKTROMAGNETISCHEN FELDES DES LICHTES (On a Possible Interpretation of the Electromagnetic Field of Light).—F. J. V. Wiśniewski. (*Ann. der Phys.*, 12th August, 1929, Vol. 56, No. 9/10, pp. 713–716.)

By making three assumptions (the first of which is to attribute an electric moment to every light quantum) the writer converts the "wave-motion" properties of light, such as polarizability, interfering power, etc., into terms of quantum mechanics. The electromagnetic field of a source of light represents the behaviour, not of the quanta themselves, but of the electric moment of a totality of quanta.

THE INTERPRETATION OF THE BEHAVIOUR OF ALGOL, AND THE VARIABILITY OF THE VELOCITY OF LIGHT.—M. La Rosa. (*Reale Acad. Naz. dei Lincei*, 5th May, 1929.)

The behaviour of Algol and analogous stars, which Bernheimer and Salet regard as disproving the writer's application of the ballistic principle to the propagation of light, is shown actually to furnish a striking confirmation of that application.

DIE REFLEXION DES LICHTES AN EINEM BEWEGTEN SPIEGEL (The Reflection of Light at a Rotating Mirror).—J. Würschmidt. (*Zeitschr. f. Phys.*, 27th June, 1929, Vol. 55, No. 9/10, pp. 646–675.)

An investigation of the processes in the Michelson-Morley experiment, leading to the conclusion that the Lorentz contraction is a real contraction of the moving material body and that the idea of a stationary ether, as the carrier of electromagnetic phenomena, can be retained.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

LA GENÈSE DES ORAGES DE CHALEUR ET LEUR PRÉVISION À L'AIDE DES ATMOSPHÉRIQUES (The Genesis of Heat Storms, and their Prediction by the help of Atmospherics).—J. Lugeon. (*Comptes Rendus*, 26th August, 1929, Vol. 189, pp. 363–365.)

These "heat" or "convection" storms, originating in an instability of the air due to an excess of humidity and of temperature in the lower layers of

the atmosphere, are frequent in Switzerland in summer. They are quite limited in extent, often being formed by one single cumulo-nimbus, and show during the afternoon. At any rate for a radius of 180 km. round Zurich, they show a very marked correlation with the curves of their atmospherics. The writer has repeatedly observed on summer days, calm to a height of 8,000 m., a very marked hump on the usual falling curve of atmospherics just before sunrise. This hump does *not* show on those days when no storm occurs, even though cumulus and strong convection may be present.

By the method of exploration previously proposed (Aug. Abstracts, p. 444) he calculates that the hump is connected with a thick layer of air, stratified and electrified, moving between heights of 4,500 and 6,000 m. It is probably a zone of temperature inversion, invisible because it contains no condensed vapour. During the formation and ascent of the cumuli, between 8^h and 11–14^h, the atmospherics are "clicks," infrequent and weak. Suddenly, between 11 and 14^h, their curve shows a very sudden rise and their frequency changes in a few minutes from about 10 to about 100 per minute. The head of the cumulus becomes cloaked in a milky veil (false cirrus) which spreads over the sky. The atmospherics change their structure and wavelength, becoming oscillating and very strong (grinders). Lightning and rain follow one or two hours later.

Sounding balloons show that the veil of false cirrus develops exactly between the heights 4,500—6,000 m. Thus the phenomenon coincides with the moment when the condensed vapours, rising by convection and gaining (according to Simpson's theory) positive electricity, come into contact with the layer mentioned above, initially of opposite polarity. As they reach this level, the droplets are dispersed horizontally, partly neutralised. The layer forms an electric barrage opposing any further upward motion, except for a moment when it has given up all its initial charge. This moment corresponds with a sudden drop in the atmospherics curve, about 10 minutes after its big rise. Then the stratified cloud puts itself quickly at the potential of the head of cumulus which it envelops. By the Brillouin effect it becomes again charged, forming thus the plate of a gigantic condenser whose negative plate is the earth. The positive charges carried by the rain, passing through the dielectric some hundreds or thousands of metres in thickness, are not enough to discharge this condenser so long as it is being fed by the convection currents. But as soon as these cease, either on account of adiabatic reasons or by the weakening of the solar radiation, a few lightning flashes neutralise the whole condensed mass and the storm ends in a few minutes (as shown by a very sharply descending atmospherics-curve).

Thus it is hardly possible, by *ordinary* observations on atmospherics, to predict such storms more than an hour or two in advance. On the other hand, by the special exploration before sunrise they can be predicted much earlier, assuming the persistence during the day of the high electrified layer—which is the case when the weather is favourable to these local storms, with a slight barometric gradient.

DIURNAL VARIATION OF ELECTRIC POTENTIAL GRADIENT.—F. J. W. Whipple. (*Journ. Roy. Meteor. Soc.*, Vol. 55, pp. 1–13.)

COMMENT ON STOPPEL'S INVESTIGATIONS INTO LOCAL VARIATIONS OF EARTH POTENTIAL.—F. Linke. (*Zeitschr. f. Geophys.*, No. 1, 1929, Vol. 5, pp. 46–47.)

The changes which Stoppel noted in his electrometer readings are here said to be due *not* to potential variations but to variations in the insulation of his apparatus; the periodicity being probably due to the daily changes of temperature and moisture. See March Abstracts, p. 147.

TURBULENCE IN THE SUN'S ATMOSPHERE.—W. H. McCrea. (*Nature*, 21st Sept., 1929, Vol. 124, pp. 442–443.)

LIGHTNING PROTECTION IN PRACTICE AND THEORY.—(*Engineering*, 23rd Aug., 1929, Vol. 128, pp. 236–237.)

IONS AND ELECTRICAL CURRENTS IN THE UPPER ATMOSPHERE.—E. O. Hulbert. (*Science*, 30th August, 1929, Vol. 70, p. 216.)

Outline of a paper to be communicated to the American Physical Society, containing further development of the writer's ultra-violet light theory (February Abstracts, p. 101, and subsequent abstracts on pages 147, 265, 324, 503). The distribution of the ions over the earth, worked out from considerations of recombination, diffusion and drift, is found to be that required by the diamagnetic theory of the solar diurnal variation of the earth's magnetism (see Gunn, 1928 Abstracts, p. 578; also August Abstracts, p. 445).

The gravitational drift currents are found to flow mainly along the parallels of latitude thus:—(1) a current sheet flowing eastwards in the levels above 150 km., which at the sunrise and sunset longitudes divides into two sheets: (2) flowing westward on the day side of the earth underneath (1) in the levels below 150 km., and (3) continuing eastward in the upper levels around on the night side of the earth. The current is mainly between the fortieth parallels of latitude, N. and S., and falls to lower values at the higher latitudes. The total currents in the three sheets are about 10^7, 8×10^6, and 2×10^6 amperes respectively. The east and west daytime sheets (1) and (2) subtract from each other, leaving an eastward current of about 2×10^6 amperes flowing round the earth all the time, and causing a magnetic field agreeing in magnitude and type with Bauer's 1922 analysis.

As a result of the drift currents, the sunset longitude of the earth is at a potential several hundred volts above that of the sunrise longitude. This electric field combined with the earth's magnetic field causes the ions and electrons on the night side of the earth to drift upward with velocities of the order of 100 cm., per sec.; they move into regions of lower pressure and therefore do not recombine as fast as they otherwise would. This removes a difficulty from an earlier calculation, which yielded too great a night-time rate of disappearance of the free charges. The upward drift of ionisation causes a rise of the Heaviside

layer which is, partially at least, compensated by the fall due to the cooling and contraction of the atmosphere at night, and is complicated by the diffusion of the ions.

"It is difficult to say how much of the night-time rise of the layer observed in experiments with wireless rays may be genuine rise and how much may be an apparent rise due to delayed group velocities, or to other causes."

PROPERTIES OF CIRCUITS.

THE FREQUENCY DEPARTURE OF THERMIONIC OSCILLATORS FROM THE "*LC*" VALUE.—S. W. C. Pack. (*E.W. & W.E.*, Sept. and Oct., 1929, Vol. 6, pp. 472–480 and 554–564.)

The preliminary sections describe the special points of the method; hitherto, in research on such oscillator frequency variation, the exact frequency departure has not been measured; the frequency has been kept constant by making small changes in the capacity of the oscillatory circuit as the conditions were varied. By the present method, L and C of the oscillatory circuit have been kept constant—as in a practical case—and the frequency differences themselves measured; the common trouble underlying the determination of small frequency differences (the "locking" tendency) being avoided by keeping the circuits electrically separated, the only connection being the brain of the observer, through the separate telephones of a double head-set.

The frequency theory, neglecting grid current, is given as developed by Gutton; a further theory of C. L. Fortescue's is also given which considers grid current. Curves of results obtained with varying conditions of coupling, filament current, anode voltage, etc., are given and are explained in the light of the theory. The "*LC*" frequency was 640 p.p.s. In most cases the variation was only about ½ cycle per sec., but in the case of adding resistance to the *LC* circuit there was a variation of 2 cycles per sec. In a practical case with a combination of small variations in the conditions the ½-cycle variation is probable. Various suggestions are put forward for further research on the subject.

OSCILLATION POWER OUTPUT OF A TRIODE SYSTEM AND PRINCIPLE OF ITS OPTIMUM DESIGN. PART I.—OSCILLATION POWER OUTPUT.—E. Takagishi. (*Res. Electrot. Lab. Tokyo* May, 1929, No. 257, 60 pp. and numerous plates.)

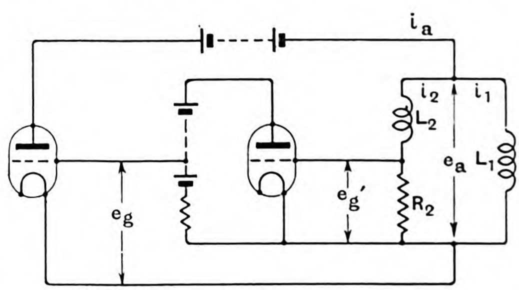
The paper begins by references to the work of Möller, D. C. Prince, Jouaust and Blanchard: so far as actual design calculations are concerned, all the results are condemned as too tedious and cumbersome or as depending on "cut-and-try" methods. The writer then sets out to develop a procedure, based on a series of experiments, to enable all the quantities concerning a triode and its associated circuits necessary for designing purposes to be obtained without elaborate calculations.

From consideration of a number of anode- and grid-current contour curves (co-ordinates E_a and E_g) reproduced from various sources including the writer's own tests, it is seen that they can all be represented approximately by a common fictitious contour curve, which in the case of the anode current curve is of a "deformed V" shape. After careful analysis of these fictitious curves, the writer obtains a similar contour curve for I_a/I_e instead of for I_a (I_e being the emission current) still keeping E_a and E_g as co-ordinates. Assuming, then, that for practical purposes it is good enough to take a single contour of one value of I_a/I_e, say 75 per cent., he obtains a simplified characteristic which he takes as the "standard characteristic" and which forms the basis of the whole theoretical calculation following. He then considers in what manner and to what degree this standard deviates from the actual characteristics. This completes the first chapter; the next begins by investigating the representation of an oscillating condition of a triode on its "standard characteristic" diagram. This leads to the classification of five different modes of oscillation, corresponding to five different wave-forms of anode current, according to the nature of the characteristic planes of the "deformed V" standard characteristic traversed by the oscillation line under consideration. It is shown how the dependable range of each kind of oscillation can be determined, together with the values of the various oscillating quantities. The present part ends with an application of the results obtained to the question of telephony and the obtaining of a linear form of modulation.

THE TRIODE VALVE EQUIVALENT NETWORK.—F. M. Colebrook. (*E.W. & W.E.*, Sept., 1929, Vol. 6, pp. 486–497.)

ÜBER SCHWINGUNGSERZEUGUNG MITTELS EINES ELEKTRONENRÖHRENSYSTEMS, BEI WELCHEM DIE KAPAZITÄT VON UNTERGEORDNETER BEDEUTUNG IST (The Production of Oscillations by a Valve Circuit in which the Capacity is of Secondary Importance).—K. Heegner & Y. Watanabe. (*Zeitschr. f. Hochf. Tech.*, Aug., 1929, Vol. 34, pp. 49–52.)

Heegner has already discussed a 2-valve circuit containing only capacity and resistance but capable of giving almost sinusoidal oscillations (Abstracts, 1927, Vol. 4, p. 573), and some of the same results



were obtained rather earlier by Roosenstein with his tetrode-multivibrator. The present article deals with such a (2-triode) circuit but with the

capacity replaced by an inductance. The condition for the setting-up of oscillations is given by

$$SR_2k' > \frac{R_2}{R_i} + 1 + \frac{L_2}{L_1}$$

where k' is a measure of the amplifying power of the second valve (e_g/e'_g) and R_i is the internal resistance of the first valve; while the frequency $\omega = \sqrt{\frac{R_2R_i}{L_2L_1}}$. The latter equation holds for small amplitudes, but fails for small values of L_2, since the electrode capacities and the self-capacity of L_1 become of importance. If $L_2 = 0$ and kk' is about 1, small oscillations are still possible $\left(\frac{1}{\omega^2} = \frac{L_1L_2}{R_iR_2} + L_1C_1,\ C_1 \text{ being an equivalent small capacity parallel with } L_1\right)$ but if $L_2 = 0$ and $kk' \gg 1$, a multivibrator oscillation sets in, as it did in the original capacity-and-resistance circuit when one capacity was reduced below a certain limit (but in the present case the times are influenced by the self-capacities mentioned above). It is pointed out that the case $L_2 = 0$ is represented by a dynatron circuit, in which an inductance is connected in the anode circuit and shunted by a resistance. This circuit is investigated for amplitude of oscillation.

It is mentioned that the system represented in the diagram can be replaced by one using one double-grid valve.

An Empirical Equation for Determining the d^2i_g/de_g^2 of Detectors.—Sylvan Harris. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1322–1325.)

Referring to Nelson's experimental method of determining the second derivative of the i_g/e_g curve (June Abstracts, p. 325) the writer points out that this method requires a knowledge of the values of the first derivative, which are usually obtained from the curve by graphical means and are subject to the same inaccuracies which the method seeks to avoid in passing to the second derivative. He considers it much more accurate, and quite simple, to obtain an empirical equation for the i_g/e_g curve: this can then be differentiated to obtain the first and second derivatives. The method of obtaining the equation is illustrated by an actual example.

Aids to the Numerical Solution of Rectification Problems.—W. A. Barclay: A. G. Warren. (*E.W. & W.E.*, Sept., 1929, Vol. 6, pp. 498–499.)

The second writer, in his paper dealt with in Oct. Abstracts, referred to Barclay's description (*ibid.*, Aug. and Sept., 1927) of his methods of approximate integration, but concluded that they are unsuitable to the type of characteristic which is most desired for rectification. In the present letter Barclay shows that on the contrary his methods can well be applied to Warren's own example, with considerable saving of labour and unimpeachable accuracy.

Reciprocal Theorem Reservations when applied to Wireless.—J. C. Schelleng. (See under "Directional Wireless.")

Aperiodische Hochfrequenztransformatoren (Aperiodic H.F. Transformers.)—H. Brykczynski. (*R., B., F. f. Alle*, September 1929, pp. 418–421.)

An article on the advantages and use of these "comparatively little-known" transformers: having a "most favoured" wave-band, they are more efficient for this band than the more strictly aperiodic choke or resistance couplings: they are particularly useful also in an input valve stage—between aerial and tuned receiver—and in this connection a particularly good (noiseless) volume control is obtained by shunting the primary with a variable resistance—or by varying the input valve filament heating. Another use is in the intermediate-frequency stages, especially for short wave reception: another, in band filters.

Theorie der elektrischen Schwingungssiebe (Theory of Oscillation Filters).—H. Schulz. (*T.F.T.*, Feb., March and June, 1929, Vol. 18, pp. 31–40, 66–74, and 179–187.)

Improvements in Electric Filters.—(French Patent 657760, Thomson-Houston, pub. 27th May, 1929.)

The use of piezoelectric oscillators in filter circuits to reduce the losses sustained in ordinary filter circuits and to improve the sharpness of cut-off.

Constantes caractéristiques des Générateurs électriques (Characteristic Constants of Electric Generators).—E. M. Galvez. (*Comptes Rendus*, 21st & 26th Aug., 1929, Vol. 189, pp. 329–331 and 360–361.)

A revision of the usual relation connecting terminal voltage V, electromotive force E, external resistance R and internal resistance Ω, namely $V = E \cdot \frac{R}{R + \Omega}$, which is not always convenient and not sufficiently general (*cf.* Chaumat, in connection with electrostatic generators, July and Aug. Abstracts, pp. 405 and 465). As a result of the writer's treatment, the voltage drop produced on closing the circuit through a resistance R is given by

$$E - V = \frac{\epsilon\rho Y}{1 + \rho R} - \frac{\epsilon\rho R Y}{\rho R Y + \rho + R}$$

where E is the e.m.f., V the terminal voltage, ϵ the generator e.m.f. for perfect insulation between its terminals, ρ the [working] internal resistance, and Y a constant named "charge conductance" such that the total generator current $I_g = Y(\epsilon - V)$. This is for the stable condition; the second note deals with the attainment of this stable condition.

The Definition of Selectivity.—F. M. Colebrook. (*E.W. & W.E.*, August, 1929, Vol. 6, pp. 422–424.)

The writer points out that the terms "selectivity" and "sharpness of tuning" (or "sharpness of resonance") are often used as if they were synonymous, whereas there is a distinct difference between them: the former refers to the variation

of behaviour of a given circuit or network with respect to different incoming frequencies, while the latter refers to its variation of behaviour with respect to a variation of some specified element of its own, the incoming frequency being kept constant. He shows that in simple cases such as that of a series resonant circuit, assuming certain given definitions, the selectivity is approximately twice the sharpness of tuning (current resonance). In rather more complex cases the relation is less simple: examples are given. The definitions are not supposed to apply to such systems as band pass filters and similar circuit combinations; the writer considers it doubtful whether any simple numerical specification could be drawn up which would be applicable both to these and to the normal types of resonance. In an editorial (p. 411) G.W.O.H. suggests that if "sharpness of tuning" were expressed in terms of that property of the variable element which has a linear relation to the resonant frequency of the circuit, *i.e.*, $\sqrt{C}$ or $\sqrt{L}$ instead of the usual C or L, the highly undesirable 2 : 1 ratio anomaly would disappear. Colebrook replies in the September issue (p. 498) by maintaining that selectivity and sharpness of tuning are quite definite and distinct ideas, that the two-to-one relationship holding in certain simple cases is not really a "highly undesirable anomaly" but on the contrary a useful emphasis of the distinction, and that the proposed modification obtains an apparent simplification in some special cases at the expense of complicating the general definition.

GENERAL SOLUTION FOR HIGH FREQUENCY TRANSFORMER AND OSCILLATING SYSTEMS.—T. J. Hodgkinson. (*Electrician*, 30th August, 1929, Vol. 103, pp. 241–243.)

DIAGRAMME ZUR BERECHNUNG VON VIERPOLEN KONSTANTEN WELLENWIDERSTANDES (Diagrams for the Calculation of Quadripoles of Constant Impedance).—V. Gandtner and G. Wohlgemuth. (*Wiss. Veröffent. a.d. Siemens-Konz.*, No. 2, 1929, Vol. 7, pp. 67–84.)

DIAGRAMME FÜR DIE PARALLELSCHALTUNG BELIEBIGER SCHEINWIDERSTÄNDE (Diagrams for the Connection in Parallel of a number of Virtual Resistances).—H. Rukop. (*Arch. f. Elektrot.*, No. 5, 1929, Vol. 21, pp. 443–448.)

VIERPOLE (QUADRIPOLES).—W. Cauer. (*E.N.T.*, July, 1929, Vol. 6, pp. 272–282.)

The behaviour under varying frequencies of quadripoles (circuits containing self-inductance, mutual inductance, positive ohmic resistance and capacity, without any internal e.m.f., and provided with a pair of input and a pair of output terminals) is investigated; the design of quadripoles of predetermined frequency characteristics and of quadripoles equivalent to a given quadripole, for any frequencies, is examined.

FORCED ELECTRIC OSCILLATIONS IN THREE CIRCUITS WITH ELECTROMAGNETIC COUPLING.—W. J. Sette and R. E. Martin. (Summary in *Phys. Review*, June, 1929, Vol. 33, p. 1075.)

THE PARALLEL CONDENSER IN FREQUENCY-MULTIPLYING CIRCUITS.—Hilpert and Seydel: Kramar. (*E.T.Z.*, 8th Aug., 1929, Vol. 50, p. 1177.)

An argument on the paper dealt with in April Abstracts, p. 207.

ÜBER DIE SELBSTERREGTEN SCHWINGUNGEN IN KREISEN MIT EISENKERNSPULEN (Self-excited Oscillations in Circuits containing Iron-cored Coils).—H. Winter-Günther. (*Zeitschr. f. Hochf. Tech.*, Aug., 1929, Vol. 34, pp. 41–49.)

Heegner, in 1924 and onwards, experimentally investigated these circuits and showed that when supplied with an external sinusoidal e.m.f. they gave, under certain conditions, subsidiary oscillations which were not necessarily equal to, or a whole multiple of, the frequency of the external e.m.f. He also arrived, by energy-considerations, at certain theoretical conclusions, particularly as to the relations between the frequencies. The present writer deals with the self-excitation of these oscillations in a different manner, based on Rayleigh's paper "On maintained vibrations." Here a string with one end connected to a tuning-fork is set into longitudinal vibration of frequency ω, and although there seems no cause for transverse vibrations, under certain conditions such vibrations are set up vigorously with a frequency $\omega/2$.

The electromagnetic analogy to this mechanical problem is provided by an oscillating circuit whose capacity or inductance is varied periodically, as would be the case for a circuit containing an iron-cored coil magnetised by an alternating current. The inductance of such a coil suffers a periodic change, of the same fundamental frequency as the a.c. if a d.c. component is present, or of double the a.c. frequency if the d.c. component is absent. The amplitudes of the fundamental and overtones of this periodic inductance-variation are functions of the effective value of the magnetising currents. Calculation leads to the differential equation obtained by Rayleigh in the mechanical case, which—as he showed—for certain values of coefficients possesses a solution representing stationary oscillations whose frequency is *half* that of the change producing them: *i.e.*, in the electrical case, half the frequency of the inductance-variation. Thus for a.c. with d.c. superposed, the self-excited oscillations have a frequency *half* that of the external e.m.f. (or a whole multiple of that half frequency) while for pure a.c. they have a frequency *equal* to that of the e.m.f.

The equations for the setting up of self-excitation are derived, and allow of calculation of the necessary tuning of the system and the magnitudes of the magnetising currents. The above is all for single circuits, but the paper ends with an extension to coupled circuits, an example of these being worked out.

POTENTIAL DIFFERENCE AND ELECTROMOTIVE FORCE.—E. A. Biedermann. (*E.W. & W.E.*, September, 1929, Vol. 6, pp. 481–485.)

A detailed examination of Wilmotte's proposed definitions for the above terms, in his paper "Some

Fundamental Definitions" (*ibid.*, November, 1928, Vol. 5, pp. 607–615). The writer says: "One is forced to the conclusion, therefore, that any attempt to generalise the meaning of potential difference by associating potential, as commonly understood, with the scalar potential of electromagnetic theory must fail, because it will not satisfy the second condition enunciated by Mr. Wilmotte that any definition must submit to the generally accepted meaning of the term." He considers that Wilmotte has omitted to take account of the fact that the scalar potential is a retarded potential, and by so doing has obscured the fact that other forces than electrostatic forces are derived from the scalar potential.

As an alternative, he suggests that the term P.D. shall be generalised to mean always the line integral of only that force which depends on the charge distribution, the force represented by $\sum \frac{[q]}{r^2} \cdot \frac{dr}{ds}$, which corresponds very closely to a true electrostatic force and forms a part in all circumstances of the force derived from the scalar potential. The line integral of all other forces, whether derived from the scalar or vector potential, would then define the e.m.f.; these other forces are all electromagnetic, depending directly on the distribution of currents and not of charges.

Über die Konstruktion des harmonischen Mittels (Graphic Construction for the Harmonic Mean).—H. Reppisch. (*Zeitschr. f. Hochf. Tech.*, August, 1929, Vol. 34, pp. 56–60.)

The graphic determination of the resistance of a paralleled system composed of similar, opposed and various composite resistances is illustrated by examples, the construction of the diagrams being explained geometrically. Among the examples are:—the parallel connection of positive and negative reactances; of negative reactance and ohmic resistance; of an impedance $(L + R)$ and a reactance.

TRANSMISSION.

Ein Sender für 3 m.–Wellen (A 3-Metre Wave Transmitter). — A. Pfeiffer. (*R., B., F. f. Alle*, September, 1929, pp. 421–423.)

Based on an article of Pfeiffer's in the Philips' Co. magazine. A Philips B409 is used as oscillator and a Philips B405 as modulator with 150–200 v. anode voltage. Practical details as to mounting, insulation, etc., are given.

Oscillation Power Output of a Triode System and Principle of its Optimum Design.—E. Takagishi. (*See* under "Properties of Circuits.")

RECEPTION.

The Wireless World Record III.—A. L. M. Sowerby and H. F. Smith. (*Wireless World*, 4th and 11th September, 1929, Vol. 25, pp. 212–218 and 244–248.)

"The highest H.F. stage gain yet attained." Three indirectly-heated Cosmos A.C. type valves are used, the r.f. stage giving voltage amplifications ranging from 515 at 250 m. to 433 at 600 m. (in the actual receiver these values will be less owing to the reverse reaction from the detector). The detector is an anode-bend rectifier in conjunction with a tuned circuit of the lowest attainable losses, making the use of reaction unnecessary. Owing to the exceptionally high efficiency of the indirectly-heated screen-grid valve in the r.f. stage, "a close approach to the very desirable characteristics of a receiver containing two r.f. stages has been attained while employing a single stage only." Full constructional details are given.

Recent Developments in Superheterodyne Receivers: Discussion.—G. L. Beers and W. L. Carlson: F. K. Vreeland. (*Proc. Inst. Rad. Eng.*, August, 1929, Vol 17, pp. 1454–1458.)

Referring to the paper dealt with in June Abstracts, pp. 327–328, Vreeland attacks various points in the design and performance of the apparatus described. (1) The overall frequency characteristic lacks the substantially rectangular form which characterises band selection at its best, and the effect of this is shown on the fidelity curve. He attributes this to the intermediate-frequency selectors and to the resonant radio-frequency circuits. He considers that the former could be designed to give a better band-form, and should have a bridging inductance coil instead of an inductive coupling (but in any case would require more material, space and elaboration than the corresponding r.f. band selector); while the latter should be not merely "broadly resonant circuits" but either a single band selector or sharply resonant circuits spaced in the frequency scale as suggested in his paper (1928 Abstracts, p. 286).

Beers, on the other hand, replies that the slightly rounded selectivity characteristic is necessary for a broadcast receiver: if the curve has a hollow top, the average user tunes to the peak on one side and side-band discrimination results. For fidelity and selectivity, the slightly rounded top is unimportant. The inductively coupled arrangement is just as convenient as the bridging inductance coil. The tuned r.f. circuits are used primarily to reduce undesired responses and are satisfactory for this without resorting to coupled circuits. There is a decided advantage in having the intermediate-frequency circuits determine the selectivity of a superheterodyne receiver, as by so doing the selectivity can be made very uniform throughout the broadcast range. This is not the case with a tuned r.f. band selector, as in the best receivers of this type the band width varies three to one from one end of the broadcast range to the other.

See also below.

Automatic Volume Control by R.F. or L.F. Voltage.—G. L. Beers; F. K. Vreeland. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1455–1458.)

Part of the above discussion. Vreeland prefers his "automatic governor" (deriving its governing e.m.f. from the audio-frequency output) to the

carrier-actuated control described: the full e.m.f. applied to the loud-speaker may be employed or stepped up by a transformer, and the scope of effective governing is thus enormously increased; an applied signal strength of 100,000 μV. or more is readily handled, as against 900 μV. shown in the paper; the governor can operate directly on the anode supply of the valves, leaving the grid bias constant and avoiding the distortion which results from an excessive increase in bias. With bias control, the most faithful reproduction occurs on the weaker signals, "which are usually no good anyway." The l.f. governor keeps the output level constant regardless of the degree of modulation: the design for "quick response and slow recovery" ensures that "changes in the dynamic of music or voice are rendered with their true relative strengths." Tuning is easier, since the gain remains substantially constant for a sufficient time to tune accurately by ear without a separate indicator.

Beers replies that the objections to the arrangement described by Vreeland are so numerous as to prohibit a discussion of all of them. Regarding the points mentioned above, the carrier-actuated control is satisfactory for a field of 100,000 μV.—the curves were plotted only up to 900 μV. merely to show in more detail the shape of the curve where the control starts to take effect. Distortion by the use of high negative biases is not eliminated by varying the plate voltage instead of the bias, "as a brief study of tube characteristic curves will show."

SELBSTTÄTIGE REGELUNG VON SCHWUNDERSCHEINUNGEN BEIM KURZWELLENVERKEHR (Automatic Compensation for Fading in Short Wave Communication).— —. Thierbach. (*E.N.T.*, Aug., 1929, Vol. 6, p. 339.)

A regulating signal of constant amplitude is transmitted on a frequency close to the telephone band, its received energy being used to regulate the amplification of the telephone amplifier. Tests show that considerable improvement results, but within limits only—owing to the fading being different even on the two neighbouring wavelengths. *Cf. Wireless World*, 17th July, 1929, p. 52, Patent 298463.

LAUTSTÄRKE-REGELUNG (Volume Control).—H. Ziegler. (*R., B., F. f. Alle*, Aug., 1929, pp. 355–361.)

An article on various hand-operated volume controls, leading up to a description of an appliance invented by the writer, which is claimed to be almost completely independent of the resistance of valve, detector or pick-up and also of the frequency. It consists of a tapped iron-cored inductance connected across the primary of the l.f. input transformer. *Cf.* same writer, March Abstracts, p. 166.

THE ORIGINAL SUPERHETERODYNE PATENT.—L. Levy. (*Wireless World*, 31st July, 1929, Vol. 25, p. 105.)

A paragraph announcing that the German Patent Office has recognised the priority claims of L. Levy for the discovery of the superheterodyne principle, holding that his French patent 493660 of 1917 clearly contains the idea of an amplification of the intermediate frequency.

SOME CHARACTERISTICS OF MODERN RADIO RECEIVERS AND THEIR RELATION TO BROADCAST REGULATION.—L. M. Hull. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1334–1341.)

"The paper gives a brief discussion of the modern tendencies in radio broadcast receiver design, with particular regard to those characteristics of receivers which are related to the problem of allocation and regulation of broadcasting stations." Twenty American receivers ("Group A") of the 1927–1928 season are compared with twenty-four of the 1928–1929 season ("Group B"). As regards "discrimination between channels" (*i.e.* relative responses to a wanted signal and to an unwanted signal of the same field intensity in an adjacent channel, having a carrier separated by 10 kc. from the wanted signal carrier), it is considered that a conservative figure for the tolerable interference level is one thousandth of the power output provided by the wanted signal. In other words, the unwanted signal should be 30 db. below the wanted signal.

At 1,000 kc. and 30 per cent. modulation, Group A gave 5 sets with 30 or more decibels, 11 gave an average of 23 db. and 4 gave less than 20 db. Group B gave 11 with 30 or more db., and the same 4 with less than 20 db. At 600 kc. both groups behaved equally well, giving 30 or more db. Thus selectivity at the higher frequencies seems to be improving.

As regards "discrimination within a channel," a similar comparison is made between the two groups. The conclusion is that the modern tendency appears to be a progressive accentuation of the lower frequencies even at the expense of the higher frequencies within a channel. Thus Group B, on a carrier frequency of 1,000 kc., gave 5 receivers which were less than 4 db. down at 50 cycles (compared with 400 cycles) to only 1 from Group A; while all of Group B were 10 db. or more (some even more than 35 db.) down at 5,000 cycles, whereas Group A gave 10 at less than 10 db. down.

The next section deals with "uniformity of reception in all channels." "There is a steady increase in the uniformity of the response of the radio-frequency filter and amplifiers in commercial receivers over the broadcast band." The next section deals with amplitude fidelity. There is a growing disposition to improve and increase those elements of the r.f. filter-system which precede the first valve of the receiver, and to discard the practice of connecting the first valve directly to an aperiodic aerial system. The use of demodulators from which the output is proportioned to the percentage modulation of the signal over a range from zero to about 90 per cent., and in which the harmonic generation is negligible even at high modulation levels, is a step of the greatest significance. Five of Group B use "power" or "linear" detectors. Detector input levels from 2 to 10 v. are now not unusual. A particularly good set in Group B has a voltage gain from the first amplifier grid to the detector grid of about 50,000, not to obtain excessive sensitivity but to operate the detector at an input of about 3 v.

The paper ends with a section on "range of reception." The tendency even in the most elaborate receivers is to choose a sensitivity of only 20 to 50 microvolts, instead of striving for one of 5 μv.; and to apply the high-amplification features of modern valves to the provision of better reproduction, higher distortionless output levels, or to the automatic control of output. This latter point is considered very important by the writer.

A STUDY OF HETERODYNE INTERFERENCE.—J. V. L. Hogan. (*Proc. Inst. Rad. Eng.*, August, 1929, Vol. 17, pp. 1354–1364.)

The first class of heterodyne interference, in broadcast reception, is that between stations on adjacent channels. Even if one is 500 cycles too high and the other 500 cycles too low, this would not ordinarily produce a troublesome background note, since the average receiver response to 9 kc. is not much better than to the prescribed 10 kc. Therefore this type of trouble can be avoided by keeping the stations strictly within the 500 cycle limit.

The second and more important class is that produced by two or more transmitters in the same channel. Here the strict enforcement of the present regulations as to accuracy of frequency is quite useless, a total discrepancy of even 100 cycles producing distressing interference. Nothing so far suggested or likely to be suggested has been successful in curing this at the receiver end, without reducing the receiver response to musical tones of the same or similar frequencies. The transmitter organisation must therefore be looked to. The writer examines this question by considering the interfering capabilities of hypothetical stations of various powers at various distances, using the formula $E_f = \frac{5.8\sqrt{P}}{d}$ to calculate the "unabsorbed" value of the radiation which he treats as the maximum to be expected under any conditions (E_f in mv./m., P in watts, d in miles), one half of this being (according to the Bureau of Standards' results) about the average night-time signal strength. Another assumption which he uses is as follows: It is recognised that a signal of 10 mv./m. at least is required to give real and continuous freedom from noise. Since a field intensity ratio of 100 to 1 gives, with modern receivers, a discrimination of about 40 db. in the audio circuits, and since 40 db. represent about the difference between ordinary speech and a just intelligible whisper, he concludes that the average noise levels rise to values well over 1/100 of 10 mv./m., *i.e.*, 0.1 mv./m.; heterodyne interference, therefore, is only troublesome if its field is as large or larger than this. His investigation leads to the conclusion that for the broadcast band, if each channel cannot be kept "clear" for one station in the U.S.A., the solution is to require each station to maintain its carrier frequency within 25 cycles of the assigned value. "In the vast high-frequency range above 1500 kc., which is rapidly coming into more and more extensive use, we should apply carefully the principles that have been taught by our experience in broadcasting. . . . In the high-frequency spectrum, as has already been done in the broadcasting band, radiating receivers will have to be discarded."

DISTURBANCE OF BROADCAST RECEPTION BY HETERODYNE APPARATUS.—F. Vilbig. (*See* under "Miscellaneous.")

IMPRESSIONS OF THE BERLIN SHOW.—(*Wireless World*, 11th Sept., 1929, Vol. 25, pp. 239–242.)

"A wide range of screen-grid mains-driven sets but few portables." The artistic merit of the exteriors of the sets has, as a general rule, taken second place to electrical and mechanical efficiency. Little wiring is done by hand, most r.f. wiring being metal ribbon riveted on an insulating material; l.f. wiring is often cabled.

ON THE AMPLIFICATION AND DETECTION OF VERY SHORT WAVES WITH DIODES.—K. Okabe. (*Journ. I.E.E. Japan*, Suppy. Issue, Jan.–Feb., 1929, pp. 28–29.)

Summary only, in English. The diode consists of a filament and a grid-shaped anode, the diameter of the glass container being several times that of the cylindrical anode. The aerial (or Hertz resonator) is coupled to the valve by an external electrode. Weak modulated waves down to 62 cm. were well received. Apparently only with the Hertz oscillator, the magnification increased enormously for a particular value of filament current.

VARIABLE INDUCTANCE RADIO TUNERS.—T. E. Lander. (*Elec. Review*, 16th Aug., 1929, Vol. 105, pp. 266–268.)

"An account of an intriguing attempt to prove the possibility of dispensing entirely with the use of tuning condensers." The writer abandoned the idea of "elastic" inductances (coils of springy wire which could be pulled out concertina-wise) and used various mechanical methods of varying the intervals between four or five coils. He says "It has been stated that for sharp tuning, when direct aerial-coil tuning is employed, a fairly large condenser is necessary; but the fact remains that critically sharp tuning can be obtained even when all tuning condensers are dispensed with, simply by making the reaction coil of a very much larger diameter than the aerial-tuning coil."

WEITERE ARBEITEN ÜBER DIE APERIODISCHE VERSTÄRKUNG VON RUNDFUNKWELLEN (Further Work on the Aperiodic Amplification of Broadcast Waves).—M. v. Ardenne. (*R., B., F.f. Alle*, Sept., 1929, pp. 391–397.)

An article based on the author's paper referred to in Aug. Abstracts, pp. 448–449.

EIN HOCHSELEKTIVER KRISTALL - EMPFÄNGER GROSSER LAUTSTÄRKE (A Highly Selective Crystal Receiver giving Great Signal Strength).—R. Vieweg. (*R., B., F.f. Alle*, Aug., 1929, p. 384.)

An "apparently unimportant" modification of circuit is here claimed to give far better selectivity than that obtainable with any other crystal circuit, while the strength of signal (provided the apparatus is carefully designed so as to keep losses down) is

enough to work a loud-speaker without any amplification. The aerial-tuning inductance leads through the crystal to earth, the crystal being shunted by a variable condenser. The telephones, shunted by a fixed condenser, are connected between aerial and earth in parallel with the first circuit.

EIN NEUER KRAFTVERSTÄRKER (A New Power Amplifier).—Telefunken Company. (*E.T.Z.*, 15th Aug., 1929, Vol. 50, p. 1190.)

An output amplifier for hotels, etc., which can be added to the ordinary loud-speaker amplifier and gives an undistorted output of 3 w.—sufficient for a number of loud-speakers (up to 8 " Arcophones "). The output valve is a Telefunken RV 218. The whole is fed from a.c. mains, two RGN 1503 rectifier valves in series being used.

AUTOMATISCHE- UND FERNBEDIENUNG VON RADIO-EMPFANGSGERÄTEN (Automatic and Distant Control of Radio Receivers).—C. Lübben. (*Funk.*, Vol. 3, 1929, p. 35: summary in *Elektrot. u. Masch:bau*, 25th Aug., 1929, p. 724.)

One of the numerous ways, complicated and simple, of distant tuning is by having an iron core in the tuning inductance and saturating this to a greater or less extent by d.c. through a control winding.

AERIALS AND AERIAL SYSTEMS.

THE ACTION OF A REFLECTING ANTENNA.—L. S. Palmer and L. L. K. Honeyball. (*Journ. I.E.E.*, August, 1929, Vol. 67, pp. 1045–1051.)

The currents produced in two tuned vertical aerials both acting as receivers in a radiation field are considered theoretically and experimentally. It is concluded :—

(1) That within one wavelength there are two critical values of the distance between two such aerials in the " end-on " position, namely, 0.33λ and 0.85λ, for which the current in the leading aerial and also the forward radiation field attain maximum values. Maximum forward radiation is incompatible with perfect reflection or zero backward radiation.

(2) For the " broadside-on " position, the best distance between the aerials, for maximum current, is 0.71λ.

(3) The values of the critical distances D for any angle β between the plane of the aerials and the direction of propagation are given approximately by the equation $\tan a\ (1 + \cos \beta) = (a^2 - 1)/a$, where $a = 2\pi D/\lambda$.

THE MUTUAL IMPEDANCE BETWEEN ADJACENT ANTENNAS.—C. R. Englund and A. B. Crawford. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1277–1295.)

Authors' summary :—" The simple theory for the computation of reflecting or multibranch antenna systems is sketched. If the points at which observations of electrical quantities are to be made are definitely specified, a knowledge of the self and mutual impedances (properly defined) between antennas is sufficient to make the computations determinate. Of the circuit constants, the most useful and accessible is the antenna current ratio

$$K_{12} = \frac{I_2}{I_1} = K_0 e^{i(\phi - (2\pi d/\lambda))}, \text{ [where } K_0 = /K_{12}/]$$

and in the work here reported ϕ has been measured in the range 0.33λ to 1λ. Experiment has shown that in this range ϕ is that theoretically calculable for a Hertzian doublet. Actually this range is equivalent to $\lambda/3$ to infinity. The discussion of experimental procedure is purposely thorough."

In the experimental work the wavelength used was about 4 m., and the experiments encountered more difficulties than were expected. All moving conductors, such as pedestrians and automobiles, definitely prevented readings when within some 50 metres ; the system actually functioned as an automatic detective, the meter-oscillations betraying any human movement within that range. " This movement passes through a cycle every time the pedestrian has altered, by a whole wavelength, the generator-pedestrian-receiver ether path." Similarly, the operator has to remain immobile at a distance, reading through field glasses.

ENCLOSED LOOP AERIAL FOR SUBMARINES.—(French Patent 658093, Telefunken, pub. 30th May, 1929.)

The Telefunken patent for a loop enclosed in a metal tube. A summary may be found in *Rev. Gén. de l'Élec.*, 31st August, 1929, pp. 79–80D.

IMPROVING THE FRAME AERIAL.—M. v. Ardenne. (*Wireless World*, 11th September, 1929, V. 25, pp. 252–253.)

An account of experiments in shielding a frame aerial by means of a screen of parallel copper wires in which the continuity of the screening wires is broken by ebonite insulators. It is claimed that the arrangement has practically no effect on distant reception, but effectually eliminates the " aerial effect " of the frame due to lines of electric force and the consequent tendency to pick up local signals and interference regardless of the direction of the frame. *Cf.* August Abstracts, pp. 450–451.

VALVES AND THERMIONICS.

ELECTRONIC EMISSION IN A VACUUM TUBE (2).—L. Tieri and V. Ricca. (Summary in *Nature*, 31st Aug., 1929, Vol. 124, p. 359.)

Continuation of the work referred to in June Abstracts, p. 331. The pure tungsten filament of a Philips' E triode is dealt with. The inversion of δI is confirmed, I being the filament current. " The interpretation of this behaviour, and the definition of the conditions under which such inversion occurs, are to be discussed later."

UN TUBO AMPLIFICATORE A VAPORI DI MERCURIO (A Mercury Vapour Amplifier Valve).—G. Giannini. (*Nuovo Cimento*, March, 1929, Vol. 6, pp. LXX–LXXI.)

A short account of a three-electrode mercury-vapour valve, taking 7–10 A. at 20–25 V. in the arc. Its efficiency as a current amplifier is very great ;

it can also function as an oscillator. The design is improved by the addition of a cooling coil at the base of the arc close to the reservoir.

POWER VALVE OUTPUT.—F. E. Henderson. (*Wireless World*, 4th Sept., 1929, Vol. 25, pp. 219–221.)

Comparative figures for undistorted a.c. energy obtainable from typical output valves are given in the form of charts. The text of the article comments on the various factors guiding the choice of a valve.

BERECHNUNG DES GÜNSTIGSTEN DURCHGRIFFES DER RÖHREN IM WIDERSTANDVERSTÄRKER (Calculation of the Optimum "Durchgriff" —$^1/\mu$—for the Valves in a Resistance Amplifier).—H. G. Möller. (*Zeitschr. f. Hochf. Tech.*, August, 1929, Vol. 34, pp. 53–56.)

For transformer-coupled amplifiers, Schottky gave the equation $D_{opt.} = 2U_g/U_a$ where U_a was the anode voltage and U_g the value for negative grid-bias which reduced the grid current to a point where it did not appreciably load the grid circuit (about −2 v.). He assumed that the anode circuit-resistance was balanced ($R_i = R_a$) and that the valve was required to give maximum output. The mean voltage at the valve anode was of course about equal to that of the anode battery.

In resistance amplifiers, where the mean anode voltage is smaller than that of the battery, it is to be expected that $D_{opt.}$ would be greater, and that very high anode voltages would have to be used if small values of D were to be employed. But von Ardenne has found that such is not the case, and that it is surprisingly easy to obtain good amplification by the use of high resistances, small values of D, and low anode voltages. The present paper investigates these results and shows how to calculate $D_{opt.}$ for the valves of resistance amplifiers.

A curve connecting "durchgriff" D with amplification factor V (V = ratio of grid voltage amplitudes on successive valves) shows a maximum. When a series of such curves is plotted for various anode resistances, it is found that for $D_{opt.}$ the value of V is always approximately $\frac{1}{2D}$.

Equations for calculating $D_{opt.}$ are then worked out and applied to two examples, one with ordinary valves and one with Loewe multiple valves. It is then seen how von Ardenne's results came about, since for the higher anode resistances $D_{opt.}$ becomes smaller: it can be even *less than* U_g/U_a—*i.e.*, a negative control voltage is worked with, which according to the Langmuir formula and its derived amplification factor would result in zero anode current and zero amplification. This is explained by the fact that in amplifiers with such high anode resistances the currents are so small that the Langmuir formula no longer applies, being replaced by the initial current equation $i = I_s e^{eU_g/KT}$.

"KONEL" METAL FOR VALVE FILAMENTS.—(*Wireless World*, 4th Sept., 1929, Vol. 25, p. 225.)

A paragraph on the use of this metal by the Westinghouse Company of America. It is said to be saving £50,000 monthly as a substitute for platinum; "the life of a Konel filament is approximately ten times longer than that of others. Valves with the new filaments are operated 175 degrees cooler than those with platinum filament, but it is stated that the emission remains the same."

NEW SCREEN-GRID VALVE: THE MAZDA 215 S.G. BATTERY-HEATED VALVE.—(*Wireless World*, 4th Sept., 1929, Vol. 25, pp. 222–224.)

The residual grid-plate capacity was found to be less than 0.006 micromicrofarad. A test on the losses introduced by the sample (unlighted) valve into a tuned r.f. circuit showed that nearly 90 per cent. of these losses were due to the base.

RECHERCHES ET ESSAIS SUR LES LAMPES DE T.S.F. (Tests and Experiments on Wireless Valves). —A. Kiriloff. (*QST Franç.*, Sept., 1929, Vol. 10, pp. 46–52.)

Another instalment of the series referred to in Aug. Abstracts, p. 452. Valves with two, three, or four sets of electrodes (German; Polytron: French, Vatea) are briefly dealt with, and the Loewe multiple valves; valves for the simultaneous reception of several different wavelengths; the "Negatron," a tetrode whose second plate is on the opposite side of the filament; the "mirror" valve of Benno and Weber, where the second plate is in the form of a parabolic mirror: a positive potential on this mirror produces increased filament-plate current; Huth's "Platron," where the grid is replaced by a concave plate, the filament coming between anode and grid.

THE PENTODE AS AN ANODE RECTIFIER.—A. L. M. Sowerby. (*Wireless World*, 18th September, 1929, Vol. 25, pp. 252–253.)

The first part of an article describing experiments with the Mullard P.M.22 valve (2-volt pentode) when used as an anode bend rectifier. The tests show that for rectification the valve must be set so as to have an initial plate current, before signals are applied, in the neighbourhood of 20 or 30 microamps when a 220,000 ohm anode resistance is used and an anode battery voltage of 145. The maximum peak voltage that the valve can accommodate with the circuit conditions chosen is about 3 volts.

The sensitivity of the pentode as rectifier, whether for large or small inputs, is seen to increase very rapidly as the anode resistance is raised. Although this effect is present also in the case of triodes, the gain in sensitivity achieved by choosing an anode resistance of the order of megohms is very much greater with the pentode.

ELEKTRONEN-RÖHREN: 3 BAND.—EMPFÄNGER (Thermionic Valves: Vol. 3.—Receivers).—H. Barkhausen. (*Zeitschr. f. Hochf. Tech.*, August, 1929, Vol. 34, p. 80.)

A review, by Scheibe, of the newly published third and final volume of Barkhausen's book.

A SPECIAL CONNECTION FOR JOINING BULBS TO VACUUM PUMPS.—(French Patent 658233, Canello, pub. 1st, June, 1929.)

A summary, with diagram, may be found in *Rev. Gén. de l'Élec.*, 31st Aug., 1929, p. 80D.

DIRECTIONAL WIRELESS.

Über Fehlweisungen bei der Funkpeilung (On Errors in Direction-Finding by Wireless).—P. Duckert. (*Zeitschr. f. Hochf. Tech.*, August, 1929, Vol. 34, pp. 60–65.)

A comprehensive survey of the research done by various workers on the several sources of error (effects due to asymmetry or stray couplings in the apparatus, to re-radiated fields, to coastal refraction, etc.) but chiefly concerning the results of the writer in correlating certain types of error with atmospheric discontinuities (*cf.* Duckert, February and April Abstracts, pp. 106–107 and 214). Results are promised soon of a 1½ year's automatic direction-finding of sources of atmospherics, which will show that the same surfaces of discontinuity which cause the d.f. errors cause also the atmospherics. The atmospheric formations involved are not always due to weather conditions, being often the result of mountains, woods or coastal formation. Typical examples are given of errors found in Autumn, 1928, for bearings of Nordholz taken at List, on an 800 m. wave. Such indirect "coast effects" may, for certain conditions of weather, wind direction and strength, simulate direct coastal refraction. The writer points out that the very marked influence of specific humidity suggests that it is the hindering of ionic mobility, rather than the actual density of ionisation, which causes the effects. He concludes by announcing that the co-operation of three d.f. stations in investigating the various types of error has resulted in obtaining important information as to meteorological conditions; a report will shortly be published.

Radio Direction-Finding by Transmission and Reception (Discussion).—R. L. Smith-Rose. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1440–1453.)

Discussion on the paper referred to in June Abstracts, pp. 332–333. Stuart Ballantine refers to reception on a rotating coil and the fact that the surroundings, refraction at the coastline, currents on land lines, etc., destroy the simple plane wave and produce at the coil an elliptical rotating magnetic field, with the result that on rotating the coil the signal does not disappear but merely goes to a minimum. In compensating for the residual signal by an e.m.f. derived from the antenna effect of the coil (or—as on battleships—from an auxiliary aerial), the amount of compensation required for a perfect minimum varies with the azimuth.

Presumably, from the reciprocity theorem, a similar compensation would be needed on a transmitting loop. L. M. Hull replied that he believed Smith-Rose had tried varying the compensation, by varying the spacings of the various wires which were strung up around the loop, to produce an antenna effect varying with the azimuth. Ballantine rejoins that the necessary variation could probably be secured by a mechanical contrivance such as the cam system used with receiving loops.

He also mentions that with the 50 or 60 Naval coastal radio compass stations the deviations ranged from 1–10 deg., depending on the site.

Hoyt Taylor speaks at considerable length on the "night effect" (a name to which he objects because the effect occurs only too often in daytime: later on, Schelleng suggests "atmospheric error"), due to components coming down from the Heaviside layer with horizontal electric polarisation. Very long waves at great distances show very little of this error because their angle of "come down" is not far from the horizontal and the horizontally polarised components are absorbed: at short distances (100 miles or so) they show the greatest errors (*e.g.* complete rotations of 360 deg.). On the other hand, 20 megacycle waves, from a distance, nearly always arrive at relatively low angles also (10 to 20 deg. from the horizontal); they also might be expected, therefore, to give very good bearings; that this is not always the case is due to their antenna structure being a much larger fraction of a wavelength above the earth, so that horizontally polarised components can come a long distance without being completely absorbed; also this short wave horizontal polarisation is more readily reflected from the surface of the earth and water.

He does not agree with Smith-Rose as to the minimum distance for "night effects." He has found occasional variations as high as 30 deg. at a distance of less than six miles.

He then deals with the Adcock system, which he considers the best thing there is for obtaining a bearing on the vertical components alone, while inclined to lament at the idea that the receiver sensitivity will have to be increased very much. On very long waves difficulty has already been experienced in getting the necessary amplification; the Adcock system is particularly needed in the h.f. band, and the required 10 to 100-fold increase in sensitivity does not seem hopeful at the present moment, when h.f. receivers pick up motor-cars and aeroplanes at several miles' distance. He urges the need for improvement here.

Another point in the paper which he queries is the remark that there is no practical difference between bearings as obtained by continuous wave and by interrupted wave: he compares this with his own early observations, where C.W. gave much larger "night effect" errors than spark transmissions, the latter merely suffering a blurring of minimum whereas with C.W., where definite patterns could be produced with sequence of phase, the minimum was distorted. He quotes also earlier English work where the same results were obtained in comparing C.W. and I.C.W.

After a further discussion of the Adcock system, S. W. Dean discusses certain contradictions regarding wave-propagation, between Radio Research Board results and results obtained in America. He refers to Hollingworth's observations of a series of gradually diminishing maxima and minima when travelling away from a long-wave station, up to a distance of a few hundred miles, and to other results he himself has observed in England; he contrasts these with the smooth curves obtained in America (at any rate below 100 kc.) and attributes the difference to a greater conductivity in the English ground. He supports this by quoting Bailey's statement that wave-antennæ in the U.S.A. have considerably greater output than those in England, owing to the greater wave-tilt (attricuted to greater earth-resistance) in the former bountry.

See also below.

ROTATING BEACON COMPARED WITH SHIP D.F. FROM NAVIGATIONAL AND ECONOMIC VIEW-POINTS.—G. R. Putnam. (*Proc. Inst. Rad. Eng.*, August, 1929, Vol. 17, pp. 1449–1452.)

Another contribution to the discussion abstracted above. The writer considers that the two systems cannot fill the same purposes, and gives a table of parallel comparison to show this. He ends: "The rotating beacon may very likely have valuable applications, either for special localities or special navigational needs; but it appears important to keep clearly in mind the requirements of radio bearings for general marine navigation, which can be met only by a truly general system."

RECIPROCITY THEOREM, THE EARTH'S MAGNETIC FIELD, AND "NIGHT EFFECT" D.F. ERRORS. —J. C. Schelleng. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 7, pp. 1452–1453.)

Part of the above discussion.

Referring first to Carson's generalisation of the theorem (*Bell Tech. Journ.*, July, 1924: see also September Abstracts, p. 506) and the conditions which are not strictly satisfied in the case of transmission through an ionised upper atmosphere, the writer dismisses as negligible (for the small amplitudes used) the additional motion produced by the motion of the ions across the magnetic field of the wave itself. A real failure of reciprocity occurs, however, when the constant magnetic field of the earth is involved; and neglecting errors due to departure from the great circle path (though such departures certainly exist, at any rate for short waves) it is the effect of this field which causes deviations in apparent bearing. If the direction of this field could be reversed, the sign of the directional error would be reversed also. With the actual constant direction of the field, a loop receiver at a spot A taking a bearing of a spot B indicates a directional error the sign of which is opposite to that observed in the same way at B on A. It would appear, at least for a horizontal magnetic field, that "regardless of the disposition of the apparatus the errors are the same as long as the directions of propagation are the same," (assuming uniform conditions along the path, and a path short compared with the earth's radius). If readings in two directions could be taken closely enough together, equal errors of opposite sign would be obtained merely by reversing the direction of propagation through the same terminal apparatus, the average thus giving a bearing free from any error due to rotation of the plane of polarisation.

ACOUSTICS AND AUDIO-FREQUENCIES.

THE ABSOLUTE MEASUREMENT OF SOUND INTENSITY.—F. D. Smith. (*Proc. Phys. Soc.*, 15th Aug., 1929, Vol. 41, Part 5, No. 230, pp. 487–499.)

Author's abstract:—An absolute measurement of sound pressure is described in which the sound is received with a moving-coil receiver. The signal heard after suitable amplification is compared with the signal produced by a small known electromotive force v applied to the receiver. It is shown that when the two signals are equal in intensity the following simple relation connects the total sound pressure P on the receiver with the electromotive force v:— $P = vHl/Z_m$, where H is the strength of the magnetic field in which the moving coil, consisting of a length l of wire, moves, and Z_m is the motional impedance of the receiver at the frequency of the sound. It is shown that the phase also of the sound can be determined with the aid of a phase-shifting transformer. Since the measurement is independent of the amplifying circuit, it is possible to use a high degree of amplification and very feeble sounds may therefore be measured.

AN ELECTRO-MECHANICAL FREQUENCY ANALYZER. —L. P. Delsasso. (*Phys. Review*, 1st Aug., 1929, Vol. 34, p. 550.)

Abstract only. The complex sound is converted, by a condenser microphone and a high quality amplifier, into potential fluctuations which are impressed on the quadrants of a special electrometer. The needle of this is suspended by three fine tungsten wires, forming a sharply resonant mechanical circuit. The period is continuously variable by changing the angular separation and tension of the suspension. The amplitude and frequency of a component can thus be found. Frequency ranges of 10–200 and 100–1700 per sec. have been obtained. The work was in connection with acoustic methods of altitude measurement for aircraft.

ZUR THEORIE DER FREQUENZANALYSE MITTELS SUCHTONS (On the Theory of Frequency Analysis by means of an Exploring Note).— H. Salinger. (*E.N.T.*, Aug., 1929, Vol. 6, pp. 293–302.)

This much-used method is first described and its theory then investigated. The exploring note, of slowly changing frequency practically linear with time, is superposed on the mixture of frequencies to be analysed: the combination is passed through a filter which removes all frequencies above a certain limit (*e.g.* 30 p.p.s.) and the residual (difference) frequencies pass on to a recorder in which the paper moves so that the abscissæ represent the frequencies of the exploring tone.

The relations between the breadth of band passed by the filter and the rate of change of the exploring frequency, and the applicability of the method to noises, transients, etc., are gone into. It is shown that the method as it stands is not applicable to "irregular noises" such as speech, but an indication is given of the lines on which the apparatus could be modified for this purpose.

A MEASUREMENT OF THE SOUND PRESSURES ON AN OBSTACLE.—W. West. (*Journ.I.E.E.*, Sept., 1929, Vol. 67, pp. 1137–1142.)

Author's summary:—An investigation of the performance of a small condenser transmitter under different conditions of test is described in Part I. The results are reduced to terms of the augmentation of the sound pressures at the surface of the transmitter, considered as an obstacle in a sound field; and a comparison is made with the calculated pressures developed on a spherical obstacle. In Part II, which is of the nature of an Appendix, the accuracies of the methods of measurement are discussed.

An Electromagnetic Monochord for the Measurement of Audio Frequencies.—J. H. O. Harries. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1316–1321.)

As a rapid means of measuring the frequency of an audio current, or of setting a source of current to a desired frequency, an electromagnetic monochord has several advantages over an electrically maintained tuning fork or series of forks. The writer experienced difficulties with the monochord described by P. K. Turner, in which a bridge sliding along the wire adjusts the length in use, and the driving is done by a magnet between whose poles the wire (carrying the current under investigation) lies. He prefers to do without a bridge and to work on a system of harmonics. A piano wire about $\frac{1}{16}$in. in diameter and about 5 feet long will go down easily to 32 cycles and up to about 5,000 cycles in harmonics, but for convenience the writer uses this wire only up to about 261 cycles (8th harmonic) using a short length (about 16in. long and $\frac{1}{32}$in. in diameter) with a fundamental of 261 cycles—middle C philharmonic—from that point up to 5,000 cycles and probably well above this. He uses a Brown loud-speaker magnet pulling direct on the wire, instead of the arrangement mentioned above.

Die Selbstaufnahme von Schallplatten mit Hilfe des Rundfunkempfängers (Making Gramophone Records from Broadcast Reception).—O. Zache. (*R., B., F. f. Alle*, Aug., 1929, pp. 365–367.)

Based on an article in the Philips' Company's "*Radio Revue*." A crystal receiver aided by two stages of L.F. amplification is shown recording on a wax-covered record. The reproduction of the wax record in a hard material is admitted to be beyond the scope of the amateur, and is also forbidden by law; but Zache's "Phonoson" discs are coated with a special composition of wax, hard at the surface and soft beneath, the soft wax hardening when exposed to the air by the track of the needle.

Study of Noises in Electrical Apparatus.—T. Spooner and J. P. Foltz. (*Journ. Am.I.E.E.*, March, 1929, Vol. 48, pp. 199–202.)

An abridgment of a paper dealing with the analysis of the noises in electrical apparatus, gearing, etc. Circuits are given of two forms of portable analysers developed for this purpose.

"Akustik": "Speech and Hearing."—F. Trendelenburg (edited by): Harvey Fletcher. (Reviews in *Nature*, 7th Sept., 1929, Vol. 124, pp. 365–366.)

Sound Propagation in Gas Mixtures.—D. G. Bourgin. (*Phys. Review*, 1st Aug., 1929, Vol. 34, pp. 521–526.)

In *Phil. Mag*, Vol. 7, 1929, p. 821, the writer presented a theory of the propagation of sound in a single gas and mixtures of two gases (*see* July Abstracts, p. 387). . The present paper extends the results on mixtures to the case of n gases and provides simpler forms for some of the earlier formulæ. It also comments from a kinetic standpoint on the rôles of viscosity and translational and internal energy conductivities.

Richtingshooren bij Sinusvormige Geluidstrillingen (Localisation by Ear of the Direction of a Pure Tone).—J. L. Van Soest. (*Physica*, July, 1929, Vol. 9, No. 7, pp. 271–282.)

Zur Theorie des Hörens (On the Theory of Hearing).—G. v. Békésy.—(*Physik. Zeitschr.*, No. 4/5, 1929, Vol. 30, pp. 115–125.)

Continuing his series of papers (*see* March Abstracts, p. 155) the writer deals here with the phenomena of fatigue.

Sur la Détermination de la Vitesse du Son, basée sur la Théorie cinétique des Gaz (The Determination of the Velocity of Sound, by a Method based on the Kinetic Theory of Gases).—S. Drzewiecki. (*Comptes Rendus*, 17th July, 1929, Vol. 189, pp. 122–125.)

By representing the static and dynamic states of a unit of a gaseous mass by a spherical surface of radius equal to the mean square of the molecular velocities, on which the Avogadro's number of molecules of mass m are uniformly distributed, the mechanism of the propagation of sound can be made clear and its velocity determined. It is suggested that this method can perhaps be applied to other forms of radiation.

PHOTOTELEGRAPHY AND TELEVISION.

Das Bildfunksystem Ranger der Radio-Corporation of America (The Ranger Picture Wireless System of the Radio Corporation).—F. Noack. (*R., B., F. f. Alle*, Sept., 1929, pp. 400–402.)

Illustrated by photographs. The transmitter is essentially similar to that of the Lorenz-Korn System, but the receiver is distinctly different, no photographic method being used. The paper strip is saturated with a sepia solution, and the picture or message is recorded—in various tones of brown—by a current of hot air (Sept. Abstracts, pp. 514–515). The control is not by varying this hot jet which is regular, but by varying a blast of cold air which opposes the heating effect of the hot jet. Apparently the cold blast is throttled down to a greater or less extent by the thread of a string galvanometer. A duplicate drum carries another paper strip, waxed in this case, and furnishes a copy which is retained at the receiving office. This copy is recorded by a hot air jet, which melts the wax. See also Aug. Abstracts, pp. 455–456, end of Zworykin discussion.

Television from 2LO. Baird Synchronising System Described. (*Wireless World*, 18th Sept., 1929, Vol. 25, p. 282.)

A short article which includes a description and illustration of Baird's method using the current which illuminates the neon tubes producing the picture. The perforated disc is driven by a small

motor on the shaft of which is mounted an iron disc with narrow teeth projecting from its circumference. The neon tube currents pass through two electromagnets. When the synchronism is perfect the teeth pass the magnets during the extremely brief "dark intervals" when no current flows through the magnet coils.

VERSUCHE ZUM FERNSEHEN. I.—BAU EINES EXPERIMENTIER-GERÄTS (Experiments in Television. I.—Construction of an Experimental Apparatus).—R. Mücke. (*R., B., F. f. Alle*, Sept., 1929, pp. 385–389.)

C. F. JENKINS TELEVISION BROADCAST TRANSMISSIONS. (*Science*, 30th Aug., 1929, Vol. 70, p. XIV.)

W3XK, in Washington, is now broadcasting "radiomovies" every night (8–9 p.m., Eastern Standard Time) on greatly increased power—but not on the 1500 kw. stated, this being evidently a misprint for 1500 w. Aeroplane television broadcasts will be attempted soon, the scene being transmitted from aeroplane to station and retransmitted with greater power.

FERNSEHEN IN AUSSICHT! (Television in Sight!)—F. Noack: v. Mihaly. (*R., B., F. f. Alle*, Aug., 1929, pp. 337–340.)

An optimistic article about the Mihaly system, a *Wireless World* article on which is referred to in Sept. Abstracts, p. 514.

NEUES BILDFUNKGERÄT VON MARCONI (A New Marconi Picture Wireless Telegraph Apparatus).—F. Noack. (*E.T.Z.*, 15th Aug., 1929, Vol. 50, pp. 1193–1194.)

An illustrated article on the Marconi-Wright Apparatus (*cf.* July Abstracts, p. 395.)

FULTOGRAPH TRANSMISSIONS.—(*R., B., F. f. Alle*, August, 1929, p. 386.)

A list of the European stations sending Fultograph transmissions.

LIGHT-SENSITIVE ELECTRIC GENERATOR.—(French Patent 657341, C^ie Gén. de Signalisation, pub. 21st May, 1929.)

One electrode, a disc of copper, has one surface covered with copper oxide. The second electrode rests on this oxide in such a way that it only partly screens it from the action of light—*e.g.*, the second electrode may be a spiral of bare wire. A glass disc covers this spiral and the whole is clamped together by a central bolt and nut. When light falls on the copper oxide, a p.d. is produced between the two electrodes, and varies with the intensity of the light.

ÜBER DAS PHOTOELEKTRISCHE VERHALTEN VON SALZEN (The Photoelectric Behaviour of Salts).—J. Werner. (*Zeitschr. f. Phys.*, 2nd Sept., 1929, Vol. 57, No. 3/4, pp. 192–226.)

The marked falling-off with time of the sensitivity of CdI_2, $PbCl_2$ and KNO_3 (in light from a quartz mercury vapour lamp) is due to the surface becoming impoverished of ions. This is investigated: among the results obtained, the sensitivity of CdI_2 increases to a maximum in the course of out-gassing and then decreases to zero. Dry gases will not restore it, only water vapour doing this.

SENSITIVITY AND SPECTRUM-RANGE OF PHOTOELECTRIC CELLS WITH SUPERPOSED SULPHUR LAYER.—(*See* Grondahl, under "Miscellaneous"; also *cf.* Olpin, Oct. Abstracts, p. 581.)

MEASUREMENTS AND STANDARDS.

MEASUREMENT OF EARTH CONDUCTIVITY FOR [VERY] SHORT ELECTRIC WAVES.—M. J. O. Strutt. (*See* under "Propagation of Waves.")

A PORTABLE RADIO INTENSITY-MEASURING APPARATUS FOR HIGH FREQUENCIES.—J. Hollingworth and R. Naismith. (*Journ.I.E.E.*, August, 1929, Vol. 67, pp. 1033–1044.)

The full paper, with discussion, a summary of which was dealt with in August Abstracts, p. 459.

A HIGH PRECISION STANDARD OF FREQUENCY.—W. A. Marrison. (*Proc. Inst. Rad. Eng.*, July, 1929, Vol. 17, pp. 1103–1122.)

See Sept. Abstracts, p. 518.

NEW GERMAN STANDARDS OF FREQUENCY.—(*E.T.Z.*, 29th August, 1929, Vol. 50, pp. 1276-1277.)

Part of an article on the 1928 work of the Imperial Physico-Technical Institute. The old standard frequency meter had an accuracy of $1 - 2 \times 10^{-4}$ (Thomson Oscillating Circuit). A standard fundamental frequency of 1,560 p.p.s. was obtained by a Karolus type tuning-fork, and a number of luminous quartz resonators were calibrated by harmonics of this throughout the range 10^3 to 10^7 p.p.s. The longitudinal vibrations have an accuracy of about $1 - 2 \times 10^{-5}$—ten times greater than that of the old standard. The frequency range 10^3 to 3×10^4 cannot be obtained by these vibrations, so transversely vibrating quartz resonators are used. The temperature coefficients of the luminous quartz resonators are very small, being for the transverse type about $- 5 \times 10^{-6}$, for the longitudinal about a fifth of this.

MAINTAINING H.F. OSCILLATIONS BY THE JOHNSEN-RAHBEK EFFECT.—F. L. Hopwood. (*See* Vincent, below, last paragraph.)

EXPERIMENTS ON MAGNETOSTRICTIVE OSCILLATORS AT RADIO FREQUENCIES.—J. H. Vincent. (*Proc. Phys. Soc.*, 15th August, 1929, Vol. 41, Part 5, No. 230, pp. 476–486.)

The full paper, a note on which was dealt with in September Abstracts, page 518, together with a subsequent discussion. Previous experiments had brought the length of the rod down to 7 mm. and the frequencies up to about 356 kc./sec. The latest tests have been with "glowray" (similar to "nichrome") bars of length 6 and 4.5 mm., placed

in a coil in series with the main inductance of a simple valve-maintained oscillating circuit; the shorter bar (2.175 mm. in diameter) gave a frequency of 540 kc./sec. No magnetostrictive effects could be found until the bars had been annealed by heating to a dull red heat in lime. "Probably much higher frequencies could be obtained from thinner and shorter bars by modifying the apparatus. Experiments on the subject are in progress."

Replying to R. W. Wood, the author said that while static magnetostriction has been studied in single crystals,* he was not aware of any work having been done on dynamic magnetostriction in such crystals. Replying to C. V. Drysdale, he agreed that solid bars must presumably be less efficient than highly laminated bars having similar elastic properties, but said that the difficulty was to preserve these properties in the composite structure. The gain due to the elimination of eddy current losses by using a split tube of nickel is largely offset by the decrease in the inertia and restoring forces as compared with those in a solid bar. Replying to C. L. Fortescue, who pointed out that the forces arising from eddy currents might amount to about 5 dynes and might perhaps take part in maintaining the oscillations, he was inclined to believe that such forces would be very small compared with those due to magnetostriction: the most striking effects are provided by oscillators of metals which are known to have high coefficients of the direct static magnetostrictive or Joule effect. He has been unable to obtain any effect with brass: an effect found with commercial aluminium may very probably be due to the forces contemplated by Fortescue. He agreed with Owen that it would be preferable to connect the oscillator in the condenser branch of the oscillatory circuit instead of in the inductance branch.

During the discussion Hopwood mentioned that he had succeeded in producing high-frequency oscillations by (apparently) making use of the Johnsen-Rahbek effect.

THE EFFECT OF TENSION AND OF A LONGITUDINAL MAGNETIC FIELD ON THE THERMO-ELECTROMOTIVE FORCES IN PERMALLOY.—A. W. Smith and J. Dellinger. (*Phys. Review*, Vol. 33, 1929, pp. 398–402.)

The effect on magnetostriction is also dealt with. In permalloys rich in nickel, tension diminishes the intensity of magnetisation in weak fields but increases the magnetostrictive contraction and the variation of thermal e.m.f.

A VERY SENSITIVE QUADRANT GALVANOMETER.—W. F. G. Swann. (*Journ. Franklin Inst.*, Aug., 1929, Vol. 208, pp. 245–247.)

The higher the potential applied to the needle the higher the voltage sensitivity, but usually 100 v. is the maximum possible without instability. This instability has now been shown to be largely due to lack of planeness of the quadrants, and by careful attention to this, making the quadrants approach planeness to the order of a wavelengh of light, 750 v. can be applied to the needle and a sensitivity of 60,000 divisions per volt can be obtained with practically complete linearity over the whole scale. Ease of adjustments remains about equal to that of the ordinary Dolezalek instrument giving about 1,000 divisions per volt. The writer has planned a mirror-cum-photoelectric device to feed into the quadrant a compensating charge, to allow for the inductive action of the needle as it swings; he hopes thus to obtain a quantity-measuring sensitivity rivalling this voltage sensitivity.

* See Akulov, June Abstracts, p. 338.

A NEW ELECTROSCOPE.—B. F. J. Schonland. (*Proc. Cambridge Phil. Soc.*, July, 1929, Vol. 25, pp. 340–343.)

The electroscope "leaf" is formed by a small rectangular mirror of thin silvered mica, hung by two fine hinges of gold leaf. A practical working limit of 40 scale divisions (1 m. distant) per volt ensures a rapid and dead-beat movement: the charging voltage in this case is about 200 v. and the time of response about one-tenth of a second.

A BALLISTIC GALVANOMETER METHOD OF POTENTIOMETRIC MEASUREMENT FOR HIGH RESISTANCE CELLS.—H. T. Beans and G. H. Walden. (*Journ. Am. Chem. Soc.*, No. 10, 1928, Vol. 50, pp. 2673–2678.)

Electrical elements of internal resistance of the order of a megohm cannot have their voltage measured in the ordinary way. A ballistic method is here described.

THE USE OF THE QUADRANT ELECTROMETER AS A BALLISTIC ENERGY METER.—P. D. Morgan and S. Whitehead. (*Journ. Scient. Instr.*, Aug., 1929, Vol. 6, pp. 241–247.)

The method is described, and formulæ given by which the sensitivity as a ballistic energy meter can be calculated from the characteristics as a voltmeter. The method is applicable to d.c. or a.c. circuits, and has so far been used to record the transient energy consumed during the operation of fusible cut-outs, etc.

A PRECISE ELECTROMETER METHOD FOR VOLTAGE-TRANSFORMER TESTING.—R. S. J. Spilsbury. (*Journ. I.E.E.*, Sept., 1929, Vol. 67, pp. 1143–1146.)

RECENT PROGRESS IN MEASURING INSTRUMENTS (Extra High Voltage).—A. Imhof. (*Bull. de l'Assoc. Suisse des Élec.*, 22nd March, 1929, Vol. 20, pp. 149–159.)

DAS SELBSTGLEICHRICHTENDE RÖHRENVOLTMETER (The Self-rectifying Thermionic Voltmeter).—C. G. Suits. (*Helvet. Phys. Acta*, No. 1, 1929, Vol. 2, pp. 3–32.)

A valve voltmeter in which anode, grid and filament are all supplied from the same a.c. source (a transformer with tappings) can give a straight line calibration characteristic. The sensitivity is half as great as with d.c. The frequency of the voltage to be measured must not be too low or it will be interfered with by overtones of the a.c. Independence of frequency is obtained between 5×10^4 and 6×10^5 per sec. Errors due to harmonics in the voltage under measurement are

considerably decreased by this method. The apparatus can also be used as a phase-meter, when the two frequencies are equal.

An Apparatus for the Measurement of Magnetic Susceptibility.—W. Sucksmith. (*Phil. Mag.*, Aug., 1929, Vol. 8, No. 49, pp. 158–165.)

A simple apparatus is described admitting of rapid measurement of magnetic susceptibilities. An accuracy of ½ per cent. is obtained on substances of moderate specific susceptibility, whilst for susceptibilities of the order of 10^{-6}, measurements can be made to 1 per cent. on half a gram of material.

Zur Messung der magnetischen Permeabilität von Eisendrähten bei Hochfrequenz in der Wheatstoneschen Brücke (The Measurement of the Magnetic Permeability of Iron Wires for High Frequency, in a Wheatstone Bridge).—K. Kreielsheimer. (*Zeitschr. f. Phys.*, 5th July, 1929, Vol. 55, No. 11/12, pp. 753–770.)

Ein Hochspannungsvoltmeter (A High Voltage Voltmeter).—A. Nikuradse. (*Arch. f. Elektrot.*, 15th June, 1929, Vol. 22, pp. 171–176.)

A new form of electrostatic voltmeter depending on the attraction of a small circular horizontal plate, enclosed in the central aperture of a very much larger plate, by a second large disc. Movement of the small disc causes a magnified movement of a small mirror.

The Modulometer: a Simple Device for Measuring the Percentage of Modulation and generally Checking the Performance of the Phone Transmitter.—J. J. Lamb. (*QST*, August, 1929, Vol. 13, pp. 8–15 and 84.)

An article on the practical use of the thermionic voltmeter for measuring modulation as described by Jolliffe (August Abstracts, p. 459).

Portable Modulation-Meters.—E. Takagishi and S. Ueno. (*Electrotech. Lab., Tokyo*, February, 1929, No. 259, 61 pp.)

In Japanese. Two types of meter are investigated and compared, on the valve trigger and the valve voltmeter principles. For a constant modulation lasting for a little while, the two types give good agreement; but for a voice modulation the valve voltmeter instrument gave readings less by 20 per cent. on the average than those of the trigger type. This discrepancy, however, was practically removed by reducing the time-constant of the valve voltmeter to about one-tenth of the original; i.e., to about 0.01 sec.

A New Resistance Testing Set.—Evershed and Vignoles. (*Engineer*, 6th Sept., 1929, Vol. 148, pp. 260–261.)

Illustrated description of the "Bridge Meg," which by the operation of a switch will measure either insulation resistances (10,000 ohms to 100 megohms), or, by a bridge method, conductor resistances (0.01 to 999,900 ohms). It consists of an ohmmeter and 500 v. generator combined in a case with a set of resistances and the necessary switches.

Unbalance in Circuits.—M. Reed. (*Phil. Mag.*, Sept., 1929, Vol. 8, No. 50, pp. 341–353.)

In cases where accurate measurements have to be made, it is necessary to take into consideration the admittance to ground of various parts of the circuits under investigation. This paper considers how these admittances can influence the accuracy of a given measurement, and how it is possible to avoid such errors. It is concluded that it is desirable, where possible, to use an unbalanced measuring circuit with one side earthed. With this type of circuit it is possible to eliminate most of the errors arising from unbalances. Where it is essential to use a balanced measuring circuit, it is necessary to employ shielded and well-balanced transformers. When connecting a balanced to an unbalanced circuit, the circuits must be separated by a shielded transformer which is balanced on the side connected to the balanced circuit.

Die Messung hochfrequenter Wechselströme mit Drehspulinstrumenten (The Measurement of H.F. Currents with Moving Coil Instruments).—R. Mücke. (*R., B., F. f. Alle*, August, 1929, pp. 351–354.)

Methods depending on the current/resistance curves of metal filaments.

New Type of Precision Frequency Changer for Instrument Calibration.—E. H. Greibach. (*Elect. Journ.*, March, 1929, Vol. 26, pp. 125–126.)

The constant frequency source (e.g., a valve-maintained tuning-fork) drives a synchronous motor which turns a replaceable stroboscopic disc through reduction gearing. This disc influences a photo-electric cell and hence (through an amplifier) a neon lamp which in its turn illuminates a second stroboscopic disc driven from a synchronous motor supplied by a variable frequency supply. The frequency meter for calibration is connected across this circuit. A difference of 0.01 of the frequency is easily detected.

The Recording of Capacity-Changes. (*E.T.Z.*, 29th August, 1929, Vol. 50, p. 1277.)

Part of an article on the 1928 work of the Imperial Physico-Technical Institute. A capacity bridge circuit is illustrated, including the condenser whose variation is to be recorded, a standard condenser, 3 variable balancing condensers for obtaining the correct amplitude and phase conditions, and two fixed resistances. The indicator takes the form of a grid-rectifying valve circuit whose anode circuit contains a compensated recording d.c. galvanometer. The anode current variations are proportional to the capacity changes.

A Capacity Measurement Method.—W. van B. Roberts. (*Journ. Franklin Inst.*, May, 1928, Vol. 205, pp. 699–701.)

A "method of discontinuity" (as contrasted with null methods or methods of adjusting to a

maximum or minimum of something) which gives very great precision with ease; reproducible readings can be made to less than a tenth of one micromicrofarad. The condenser X to be measured, in parallel with a calibrated variable condenser S of greater maximum capacity, is connected across an inductance of low resistance. One side of the condensers is earthed. The circuit is variably coupled to an oscillator, whose frequency is such that it tunes into the circuit when the unearthed pole of X is disconnected and S is near its maximum. Nearby there is a receiver (preferably with loud-speaker) together with its heterodyne.

By adjusting the mutual inductance M of the variable coupling, and the amount of reaction in the oscillator, a condition is reached in which, as S is increased, a point is passed where the beat note in the receiver changes discontinuously to a different pitch. If S is then decreased, the discontinuity in pitch occurs again, this time at a value of S slightly smaller than before. By careful adjustment of M these two critical values of S can be brought easily within a half of one micromicrofarad of each other. When this has been done, X is measured by noting the critical readings of S with and without X in parallel. The method is applicable also to inductances, etc.

SUBSIDIARY APPARATUS AND MATERIALS.

Un Travail expérimental recent sur la Théorie de l'Accumulateur au Plomb (A Recent Research on the Theory of the Lead Accumulator).—Ch. Féry: A. P. Rollet. (*Rev. Gén. de l'Élec.*, 31st Aug., 1929, Vol. 26, pp. 319–323.)

Rollet's new results confirm Féry's theory of the reaction representing the charge and discharge of the lead accumulator. According to this, the action of the negative plate is given by $Pb \rightleftarrows Pb_2SO_4$; the usual (Gladstone and Hibbert) theory being $Pb \rightleftarrows PbSO_4$. The new results can only fit in with the latter reaction by admitting the following "rather surprising" fact—that whatever the experimental conditions may be, only one-half of the active negative material is susceptible to being used.

Über Hochohmwiderstände und ein neues Verfahren zu ihrer Prüfung (High Ohmic Resistances, and a New Testing Process for Them).—G. Leithäuser. (*E.N.T.*, Aug., 1929, Vol. 6, pp. 335–338.)

After an introduction dealing with the first silicon-carbide high resistances and with the development of the more modern resistances consisting of thin layers of carbon, carbide or metallic oxides deposited (generally by sputtering) on an insulating core, the writer devotes himself to various practical points concerning these: the importance of large load-carrying powers—in power amplifiers they already have to stand up to ½ w. per cm.^{2}; since their temperature coefficient is generally negative, its value must be kept low not merely for constancy's sake, but because of the cumulatively increasing effect of a slight overload if the coefficient is at all large; microphonic noise—Riepka's patented method of testing, making use of the Barkhausen effect (reversal of magnetism). He then points out that the d.c. methods of testing generally employed are not really suitable or satisfactory, since the resistances are used in a.c. circuits. He has evolved, for the makers of the "Dralowid" resistances (June Abstracts, p. 342), a test process using high frequencies. A quenched-spark generator is employed, giving 50 kw. for loading 50,000 resistances up to 1 w. each.

Glass Window Cathode Ray Tubes.—C. M. Slack. (*E.T.Z.*, 15th August, 1929, Vol. 50, p. 1211.)

A paragraph, from the Westinghouse Tech. Press Service, on the tube referred to in March Abstracts, p. 163. The window is of thin glass (less than 12.7 μ). The process of manufacture is as follows:—the glass-blower strongly heats the far end of a little bulb of thin special glass, sucks the air out quickly and so produces a hemispherical inward bulge. The bulb is then fused on to a larger tube fitted with electrodes.

Westinghouse "Osiso" Oscillograph.—J. W. Legg. (*E.T.Z.*, 15th August, 1929, Vol. 50, pp. 1206–1207.)

Illustrated description, taken from the *Electric Journal*, Vol. 24, of this special design of loop oscillograph.

The Neon Lamp as a Stabiliser: How Feed-back can be Avoided in Eliminators.—S. O. Pearson. (*Wireless World*, 28th Aug. and 4th Sept., 1929, Vol. 25, pp. 200–202 and 229–230.)

"The neon lamp may thus be looked upon as a sort of trap which prevents voltage changes at either end of the circuit from getting through to the other end, besides limiting to a small figure the voltage changes across the load itself." *Cf.*, Körös, Aug. Abstracts, p. 460. In the present article one neon lamp is connected as a shunt, between eliminator and receiver, to prevent "motor-boating," etc.

Radio Battery Eliminators.—(*Elec. Review*, 14th June, 1929, Vol. 104, pp. 1048–1049.)

"Some notes and advice on the practical aspects of anode-circuit battery eliminators. . . ."

The Aluminium Electrolytic Condenser.—R. E. W. Maddison. (*Phil. Mag.*, July, 1929, Vol. 8, No. 48, pp. 29–55.)

Valve Effect of Electrolytic Cells.—L. Dubar and R. Audubert. (*Rev. Gén. de l'Élec.*, 16th March, 1929, Vol. 25, pp. 399–403.)

Continuation of the argument electronic *versus* electrochemical theory, referred to in June Abstracts, p. 340.

A.C. Rectifiers.—A. Soulier. (*Bull. de la Soc. franç. des Élec.*, April, 1929, Vol. 9, pp. 381–387.)

A paper covering the same ground as that dealt with in June Abstracts, p. 342.

THE CASTLE SINE-WAVE ALTERNATOR.—J. H. Holmes & Co. (*Engineering*, 23rd Aug., 1929, Vol. 128, pp. 230–232.)

Primarily designed for meter testing, this plant consists of two sine-wave alternators coupled together and driven by a d.c. motor. The phase of one alternator, as compared with that of the other, can be regulated by adjusting its stator frame, which is rotatable through an arc exceeding one pole pitch.

HIGH TENSION DIRECT CURRENT GENERATORS.—(*Elec. Review*, 19th April, 1929, Vol. 104, pp. 721–722.)

Notes on the manufacture of German machines for Wireless and laboratory purposes.

GERMAN P.O. POWER PLANTS FOR WIRELESS PURPOSES.— —. Stüber. (*E.T.Z.*, 29th Aug., 1929, Vol. 50, pp. 1256–1257.)

ERSATZSCHALTUNG FÜR DIE RÜCKWIRKUNG DER ZUNGE DES RESONANZTELEPHONS (Equivalent Circuit for the Reaction of the Reed of a Tuned Telephone).—F. Bergtold. (*Zeitschr. f. Instr : kde*, No. 8, 1928, Vol. 48, pp. 400–404.)

A VARIABLE CONDENSER WITHOUT INITIAL CAPACITY.—(*E.T.Z.*, 29th Aug., 1929, Vol. 50, p. 1277.)

Part of an article on the 1928 work of the Imperial Physico-Technical Institute. The variable condenser is connected in a bridge-circuit in such a way that the plate-to-plate capacity is effective but the component to earth does not come into the measurement, or only indirectly. If now a conducting separator, connected to the earthed case, is slid between the plates, the plate-to-plate capacity is gradually reduced to zero.

SPARKING AND ARCING AT RELAY CONTACTS.—A. H. Jacquest and L. H. Harris. (*Inst. P.O. El. Eng., Paper No.* 118, 74 pp.)

The life of contacts made of various alloys is dealt with.

RELAYS FUNCTIONING AT A REQUIRED POWER FACTOR.—(British Patent 315679, G. L. Porter and Ferranti Ltd., 12th April, 1928.)

The relay has two coil elements associated with a network of impedances. A rise in power factor produces an increase of current in one coil and a decrease in the other: the effects of the two coils can be made to balance at any determined value of power factor.

MAGNETIC LOSSES OF IRON IN HIGH FREQUENCY ALTERNATING CURRENT FIELDS.—J. R. Martin. (*Phys. Review*, April, 1929, Vol. 33, pp. 621–624.)

Frequencies ranged from 520 to 968 kc. The loss is found to increase with frequency in small samples and to decrease with frequency in larger samples. At any particular frequency the loss per unit volume is less the greater the area. These results are due to the magnetic shielding effects of eddy currents in the larger samples, and the disagreement between previous investigations may thus be explained.

ZUR BEURTEILUNG VON EISENKERNEN IN DER SCHWACHSTROMTECHNIK (Considerations in the Design of Iron Cores in Small-Current Apparatus).—G. Lohrmann. (*Wiss. Veroffentl. a. d. Siemens-Konz.*, No. 2, 1929, Vol. 7, pp. 163–196.)

NOUVEL ALLIAGE MAGNÉTIQUE (A New Magnetic Alloy).—Siemens and Halske Co. (*Génie Civil*, 31st Aug., 1929, Vol. 95, p. 215.)

French patent 653460 for an alloy of great permeability, containing nickel, iron and silicon, and prepared by a special process of heating.

DIE ABISOLIERUNG VON EMAILDRÄHTEN (The Cleaning of Enamel-covered Wires).—(*R., B., F. f. Alle*, August, 1929, p. 363.)

Paragraph on an article in *Funkbastler* pointing out that the usual method (heating and then rubbing with a pad soaked in alcohol) is not always satisfactory even after several repetitions. Bockelmann's method is recommended, needing no heating; a rag soaked in acetone is used.

DAS VERSILBERN VON KURZWELLENSPULEN (The Silver-Plating of Short Wave Coils.)—H. Thesing. (*R., B., F.f. Alle*, August, 1929, pp. 372–373.)

Description of a simple plant and method, employing as the source of silver the used fixing bath solution obtainable from a photographer.

PERTES DIÉLECTRIQUES : LEUR MESURE DANS LA TECHNIQUE INDUSTRIELLE (Dielectric Losses : Their Measurement in Industrial Technique).—J. Absil. (*Bull. de la Soc. belge des Élec.*, Jan. and March, 1929, Vol. 43, pp. 1–12 and 73–81.)

The writer lays stress on the advantages of determining the dielectric losses of raw materials, and even of finished articles, instead of (or in addition to) the usual high tension tests. Methods are described.

STATIONS, DESIGN AND OPERATION.

AN OUTLINE OF THE RADIO INSPECTION SERVICE.—A. Batcheller. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1365–1376.)

An article on the R.I.S. of the Department of Commerce. The subject matter is "historical and administrative, the latter including matters of engineering and law enforcement."

BROOKMAN'S PARK BROADCASTING STATION—"LONDON REGIONAL." (*Wireless World*, 18th Sept., 1929, pp. 288–289.)

A short illustrated outline of this station. It is mentioned that owing to limitations on the height of masts in the district, the masts have been restricted to 200 ft.

Heterodyne Interference in U.S.A. Broadcast Reception. (*See* Hogan, under "Reception.")

The Regulation of Broadcasting Stations as a Systems Problem.—E. L. Nelson. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, p. 1342.)

Short abstract only.

Some Principles of Broadcast Frequency Allocation.—L. E. Whittemore. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1343–1353.)

Engineering Aspects of the Work of the Federal Radio Commission.—J. H. Dellinger. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1326–1333.)

United States Radio Broadcasting Development.—R. H. Marriott. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1395–1439.)

Author's summary :—Part I of this paper gives in detail the development of radio broadcasting in the United States from 1907 to 1928, inclusive; Part II deals with the development of a radio broadcast from the studio to the listener. The characteristics and trends of these developments are then used for the purpose of pointing out possible future developments in radio broadcasting in Part III.

The New Berne Lists. (*Wireless World*, 4th Sept., 1929, Vol. 25, p. 224.)

A paragraph on the five volumes which now constitute the "Berne List." The contents and price of each volume are indicated.

Extension of Polish Broadcasting Organisation. (*Nature*, 28th Sept., 1929, Vol. 124, p. 493.)

The organisation is to be remodelled, following the English example, so as to provide alternative programmes for the greater part of the country. The new equipment (Marconi Company) will comprise one 120 kw. aerial input transmitter, two 16 kw., and three local relay stations working on a common wavelength with tuning fork control.

The Wave Propagation of the "Deutschland" Transmitting Station.—F. Kiebitz. (*See* under "Propagation of Waves.")

Der Deutsche Kurzwellen-Rundfunksender (The German Short Wave Broadcast Transmitter).—A. Semm. (*T.F.T.*, June, 1929, Vol. 18, pp. 187–190.)

Wireless Reigns in Turkestan.—L. Strong. (*Discovery*, Sept., 1929, Vol. 10, pp. 292–294.)

"The Russian Government is making full use of wireless in administering its Central Asiatic territory, and especially remarkable are the developments in Turkestan during the past two years. The principal broadcasting station is at Tashkent, which the writer visited."

Le Multiplex Marconi-Mathieu pour Radiosignalisation (The Marconi-Mathieu Method of Multiplex Signalling).—G. A. Mathieu. (*QST Franç.*, July, 1929, Vol. 10, pp. 15–19.)

A French version of the article referred to in September Abstracts, p. 523.

GENERAL PHYSICAL ARTICLES.

Note on the Zeeman Effect.—W. H. Watson. (*See* under "Propagation of Waves).

Two Distinct Kinds of Molecule in Hydrogen.— —. Bonhoeffer. (*Nature*, 21st Sept., 1929, Vol. 124, p. 455.)

The new mechanics predicted that two protons and two electrons could link together to form a normal hydrogen molecule in two quite different ways. Bonhoeffer has now shown that ordinary hydrogen consists of two molecular species (each with the formula H_2), has prepared at least one form in a practically pure state, and has found a number of its physical constants, which are not the same as those of ordinary hydrogen. *Cf.* McLennan and McLeod, *ibid.*, 2nd Feb., 1929, p. 160.

Über die magnetische Auslöschung der Jodfluoreszenz (The Magnetic Quenching of Iodine Fluorescence).—O. Oldenberg. (*Zeitschr. f. Phys.*, 2nd Sept., 1929, Vol. 57, No. 3/4, pp. 186–191.)

Über die Dielektrizitätskonstanten einiger Metalldämpfe (On the Dielectric Constants of some Metal Vapours).—F. Krüger and F. Maske. (*Physik. Zeitschr.*, 15th May, 1929, Vol. 30, No. 10, pp. 314–320.)

Two-dimensional Periodic Orbits in the Field of a Non-Neutral.—M. A. Higab. (*Phil. Mag.*, May, 1929, Vol. 7, No. 45, pp. 783–792.)

The motion of a charged particle in the field of an electric doublet is discussed. Earlier work (e.g., Wrinch, 1923) has limited itself to semicircular orbits for periodic paths, but Greenhill suggested the discussion of possible closed orbits: the present writer establishes the existence and studies the nature of such orbits.

Diffraction of Cathode Rays—III.—G. P. Thomson. (*Proc. Roy. Soc.*, 2nd Sept., 1929, Vol. 125 A, pp. 352–370.)

A continuation of the work referred to in 1928 Abstracts, p. 526. The paper begins by describing a technique for making metal films of the order of 10^{-6} cm. thick, approximately free from holes.

Bemerkungen zum Versuch Thomson's (Remarks on G. P. Thomson's Research).—S. C. Kar. (*Naturwiss.*, 13th September, 1929, Vol. 17, p. 727.)

Thomson and Davisson and Germer seem to have come near to proving the existence of de Broglie waves by obtaining, with retarded cathode rays, wave-trains agreeing in wavelength with those of

the de Broglie theory. However fruitful Schrödinger's conception of material waves may have been, the idea of waves carrying no energy and travelling with a velocity greater than that of light is very difficult to accept. The writer suggests the following as a plausible, though incomplete, interpretation of the phenomena in question:—if, instead of Einstein's photoelectric equation (based on the energy-law), the maintenance-law of the impulse is taken, the equation obtained is

$$\frac{h\nu}{c} = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}},$$

or—as the velocity of light is in question—

$$\lambda = \frac{h\sqrt{1 - \frac{v^2}{c^2}}}{m_0 v}.$$

But this is exactly the equation encountered in Thomson's experiment, and seems to indicate that the waves are light waves. Why the one maintenance-law should be thus favoured, when both of them are valid for the Compton theory of the interaction of radiation and electrons, remains to be explained, as does the reason why the waves are deflected by external magnetic or electric fields.

Über den gyromagnetischen Effekt und die magnetische Ablenkung von Atomstrahlen auf Grund der neuen Theorie des Magnetismus (The Gyromagnetic Effect and the Magnetic Deflection of Atomic Beams interpreted by the New—Honda's—Theory of Magnetism).—K. Honda. (*Zeitschr. f. Phys.*, 16th Aug., 1929, Vol. 56, No. 11/12, pp. 857–861.)

Longitudinal Magnetic Effect on Beams of Slow Electrons (Periodic Concentrations and Dilatations).—J. Thibaud. (*Journ. de Phys. et le Rad.*, April, 1929, Vol. 10, No. 4, pp. 161–176.)

An investigation of the phenomena referred to in April Abstracts, p. 224. The interpretation of the effects, and the laws regulating them, are given. For very slow electrons (less than 200 v.) the beam in its compressed form takes on the appearance of a thread and keeps it even after passing through a field of many thousand gauss (apparent "cohesion" of electrons: magnetic moments ?). Beams of very slow electrons of about 100 v. excite great fluorescence in various substances, particularly crystals. This property disappears for voltages of 300 or more.

Über den Durchgang langsamer Kathodenstrahlen durch Metalle (On the Passage of Slow Cathode Rays through Metals).—A. Becker. (*Ann. der Phys.*, 15th July, 1929, Series 5, Vol. 2, No. 3, pp. 249–263.)

Über das Massenverhaltnis von Proton und Elektron (On the Ratio of the Masses of Proton and Electron).—R. Fürth. (*Naturwiss.*, 30th Aug., 1929, Vol. 17, pp. 688–689.)

Calculations leading to a confirmation of the idea that this ratio μ has a theoretical connection with $z\left(=\frac{hc}{e^2}\right)$. An equation is obtained whose roots are $\mu = kz - 2$ and $\frac{1}{kz - 2}$; under certain reasonable assumptions k is found to be 32/15, so that $\mu = 1836$ (while the experimental value is 1846).

Die Abweichungen von Ohmschen Gesetz bei hohen Stromdichten im Lichte der Sommerfeldschen Elektronentheorie (Deviations from Ohm's Law at High Current Densities, in the Light of Sommerfeld's Electronic Theory).—H. Margenau. (*Zeitschr. f. Phys.*, 13th July, 1929, Vol. 56, No. 3/4, pp. 259–261.)

Zur Elektrodynamik des rotierenden Elektrons (On the Electrodynamics of the Spinning Electron).—I. Tamm. (*Zeitschr. f. Phys.*, 6th June, 1929, Vol. 55, No. 3/4, pp. 199–220.)

Zur Theorie des Lichtes (On the Theory of Light).—F. v. Wiśniewski. (*Zeitschr. f. Phys.*, 6th June, 1929, Vol. 55, No. 3/4, pp. 221–230.)

A generalisation of the Maxwell equations is proposed, and it is shown that these generalised equations correctly represent the behaviour of light in a material medium.

Artificial Disintegration of Atoms and their Packing Fractions.—H. Pettersson. (Summary in *Science Abstracts*, Sec. A., 25th May, 1929, Vol. 32, p. 441.)

Über den Begriff der Geschwindigkeit in der Diracschen Theorie des Elektrons (On the Conception of Velocity in the Dirac Theory of the Electron).—V. Fock. (*Zeitschr. f. Phys.*, 1st June, 1929, Vol. 55, No. 2, pp. 127–140.)

"To one and the same 'classical' mechanical quantity—the speed of the electron—there correspond in the Dirac theory two different quantum-mechanical quantities; these can be considered to represent the corpuscular and the wave velocities."

Les Vérifications récentes de la Mécanique ondulatoire dans le Cas des Electrons (Recent Verifications of Undulatory Mechanics in the Case of Electrons).—M. de Broglie. (*Génie Civil*, 8th June, 1929, Vol. 94, pp. 549–551.)

A full summary of a recent lecture before the French Society of Civil Engineers. After describing the various theoretical points reached by modern workers, the lecture deals with the experimental results of Davisson and Germer, G. P. Thomson, E. Rupp, and Ponte.

Les Nouvelles Conceptions sur la Matière et le Rayonnement (The New Ideas of Matter and Radiation).—A. Boutaric. (*Génie Civil*, 25th May, 1929, Vol. 94, pp. 500–503.)

First part of a simple explanation of the new

ideas and of the experimental results which have led to their formulation.

La Théorie électronique de l'Éther et l'Électromagnétisme (The Electronic Theory of the Ether, and Electromagnetism).—A. Véronnet. (*Comptes Rendus*, 3rd June, 1929, Vol. 188, pp. 1488–1490.)

A previous Note (*ibid.*, 27th May, 1929) having explained how an ether in stable equilibrium, composed of negative electrical particles (electrons or sub-electrons), would explain the propagation of light waves, the present Note extends the idea to the fundamental laws of Maxwell and Laplace. "Thus the whole of electromagnetism would be re-built and explained simply by electrons and their movements."

A Generalisation of Heaviside's Expansion Theorem.—W. O. Pennell. (*Bell Tech. Journ.*, July, 1929, Vol. 8, pp. 482–492.)

"It is thought that this extension to the expansion theorem will be of value as another way of evaluating in closed form certain operational expressions, especially those involving fractional exponents."

Sur l'Électrodynamique : Théorie classique, Développement moderne (Electrodynamics : a Modern Development of the Classical Theory).—R. Ferrier. (*Rev. Gén. d. l'Élec.*, 27th April, 4th and 11th May, 1929, Vol. 25, pp. 635–644, 677–682, and 715–721.)

Zur Physikalischen Kritik von Schrödingers Theorie der Lichtemission (The Physical Criticism of Schrödinger's Theory of the Emission of Light.) Parts I, II and III.—J. Stark. (*Ann. der Phys.*, 7th May, 1929, 5th Series, Vol. 1, No. 8, pp. 1009–1040.)

The Nucleus as Radiator.—W. M. Hicks. (*Phil. Mag.*, July, 1929, Vol. 8, No. 48, pp. 108–114.)

Gewöhnliche Materie und strahlende Energie als Verschiedene "Phasen" eines und desselben Grundstoffes (Ordinary Matter and Radiant Energy as Different "Phases" of one and the same Fundamental Material).—W. Anderson. (*Zeitschr. f. Phys.*, 12th April, 1929, Vol. 54, No. 5/6, pp. 433–444.)

Über die Grenzdichte der Materie und der Energie (On the Limiting Density of Matter and Energy).—W. Anderson. (*Zeitschr. f. Phys.*, 16th Aug., 1929, Vol. 56, No. 11/12, pp. 851–856.)

Stoner's theory on the limiting density of stars is criticised ; the compressibility of electrons and protons is discussed. The levelling property of extreme pressure is pointed out : diminution of volume for the electron begins at 5.68×10^{30} dynes per sq. cm., for protons at 6.56×10^{43} dynes. At the latter pressure all differences of volume and mass between electrons and protons disappear : the opposition in the sign of their charges remains, but this plays a decreased rôle since the mass increases so that the ratio of charge to mass decreases.

A Molecular Theory of Friction.—G. A. Tomlinson. (*Phil. Mag.*, June, 1929, Vol. 7, No. 46, pp. 905–939.)

A New Conception of the Mechanism of Metallic Conduction.—H. M. Barlow. (*Phil. Mag.*, Sept., 1929, Vol. 8, No. 50, pp. 289–304.)

This theory follows on the work dealt with in August Abstracts, p. 464.

Zur Theorie des Radiometers (On the Theory of the Radiometer).—P. S. Epstein. (*Zeitschr. f. Phys.*, 27th April, 1929, Vol. 54, No. 7/8, pp. 537–563.)

Radiometer Effect of Positive Ions.—C. T. Knipp and W. S. Stein. (*Phil Mag.*, Jan., 1929, Vol. 7, pp. 70–79.)

Contrary to previous belief, a part at least of the bombardment of a beam of positive rays results in direct mechanical effect. The proportion between radiometer and mechanical effects is suggested tentatively as 1 to 3 or 4.

MISCELLANEOUS.

How Electricity Does Things.—Ll. B. Atkinson. (*Journ. I.E.E.*, Aug., 1929, Vol. 67, pp. 937–945.)

The Fifth Faraday Lecture.

Die Fernmeldetechnik im Spiegel der E.T.Z. (The Science of Telephony in the Mirror of E.T.Z.).—E. h. Feyerabend. (*E.T.Z.*, 3rd January, 1929, Vol. 50, pp. 3–5.)

A history of telephonic development (including also Wireless telegraphy) as recorded from time to time in *E.T.Z.* since that journal's birthday 50 years ago.

The Rôle of Physics in Modern Industry.—L. O. Grondahl. (*Science*, 23rd Aug., 1929, Vol. 70, pp. 175–183.)

Among some of the recent contributions of physics to industry, the writer deals with the Kodacolor process of coloured moving pictures ; Pfund's goggles to protect workmen against ultra-violet and infra-red radiations, consisting of a thin sputtered layer of gold protected by glass ; and the increased sensitivity and spectrum-range of photoelectric cells by the superposition of a layer of sulphur on the light-sensitive layer.

Zwanzig Jahre Arbeit am Physikalischen Weltbild (20 years' work in Physics).—M. Planck. (*Physica*, June, 1929, Vol. 9, pp. 193–222.)

A long lecture, in German, on the developments in Physical Theory in the last twenty years.

Wireless at the Leipzig Fair, 1929.—(*E.T.Z.*, 6th June, 1929, Vol. 50, p. 814.)

A short commentary on various exhibits. One tendency noted is to compress long-distance

receivers into a small space: single knob adjustment and large wave-range are also to the fore. In loud-speakers, one firm tries to combine the advantages of the dynamic system with those of the electromagnetic system by means of "an elastic connection between the membrane and the radiating wall" (strahlwand). A pick-up by F. Paul (Berlin) works on the dynamic principle. The "Kondax" is a telephone receiver without coils, magnets or diaphragm: it works purely electrostatically and is extraordinarily light. Various cures for interference from power-lines, motors, etc., are shown.

ITALIENISCHER NATIONALRAT FÜR FUNKTECHNISCHE FORSCHUNGEN (The Italian National Council for Radio Research).—(*E.T.Z.*, 30th May, 1929, Vol. 50, p. 791.)

A paragraph on the recent inauguration by Mussolini of this Council (of which G. Marconi is president) and on the book edited by Pession in honour of this event. This deals with the position of Radio in Italy, and contributors include Marconi, Vallauri, Pession and Montefinale, Vanni, Sacco, and Vecchiacchi.

LES RADIOTÉLÉGRAMMES "SEISMO" (Radiotelegrams prefixed "Seismo").—E. Rothé. (*QST Franç.*, Sept., 1929, Vol. 10, pp. 25–31.)

The interpretation and utilisation of the earthquake warnings issued by radiotelegraphy.

PLAN EINER FERNSPRECHKABELVERBINDUNG ZWISCHEN EUROPA UND AMERIKA (Plan for a Telephonic Cable Link between Europe and America).—K. W. Wagner. (*Berl. Ber.*, No. 6/7, 1929, pp. 109–121).

The possibility of such a link is discussed optimistically. It is suggested that such a cable could be used also for telegraphy (sub-audible frequency) and eventually for picture telegraphy.

COMPOSITED TELEGRAPH AND TELEPHONE WORKING.—J. M. Owen and J. A. S. Martin. (*P.O. Elec. Eng. Journ.*, July, 1929, Vol. 22, pp. 89–95.)

A paper on simultaneous telegraphy (with sub-audible frequencies) and telephony, on a loaded underground circuit. It ends by quoting the proposals, recently proposed and now being reviewed by the C.C.I. conference in Berlin, for 8 requirements to be satisfied in circuits using this mode of working.

TELETYPE MODEL 14.—(*E.T.Z.*, 18th July, 1929, Vol. 50, pp. 1043–1049.)

First part of a very detailed description of this typewriter keyboard system of telegraphy (see Abstracts, 1928, Vol. 5, p. 649) which has been introduced from America to Germany and is now being tested by the German P.O. for use for public telegraph service. It gives a speed of about 7 letters per second—and is particularly simple to work and maintain.

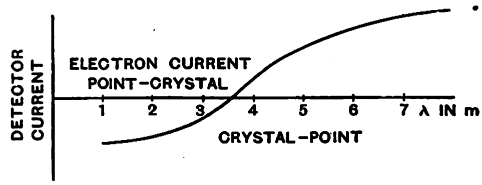
VOICE-FREQUENCY TELEGRAPHS.—W. Cruickshank. (*Journ. I.E.E.*, July, 1929, Vol. 67, pp. 813–842.)

A discussion of the position of telegraphy in this country, compared with Germany and the U.S.A., is followed by a consideration of multiplex a.c. transmission and its limits, a description of the various systems in use, and proposals for its wider adoption in this country.

A METHOD OF DETERMINING THE AXIAL RATIO OF A CRYSTAL FROM X-RAY DIFFRACTION DATA.—M. L. Fuller: W. P. Davey. (*Science*, 23rd Aug., 1929, Vol. 70, pp. 196–198.)

UMKEHR DES GLEICHGERICHTETEN DETEKTORSTROMES BEI SEHR HOHEN FREQUENZEN (Reversal of the Rectified Crystal Detector Current at Very High Frequencies).—H. E. Hollmann. (*Naturwiss.*, 13th Sept., 1929, Vol. 17, p. 728.)

Schleede and Buggisch maintained that the electron current of any crystal detector combination, for small loads, always flowed from the metal point to the crystal; but Reissaus (July Abstracts, p. 403) showed that occasionally a microscopically sharp angle of the crystal would act as a "point" to the blunt metal point. But even this does not fully represent the facts, since the writer has shown that at very high frequencies reversals take place, even with currents so small (10^{-6} A.) that no heating effect or disturbance of the crystal structure can be likely as in the experiments of Collet and of Flowes. He has now found certain detector combinations with which, in addition to the reversal at increased energy input, a reversal takes place for a change of frequency, as is shown in the curve reproduced.



The critical wavelength, at which the detector current is zero, is here shown at 3.6 metres; but for different adjustments of the same crystal it may vary between 3 and 5 metres. The phenomenon was found with galena and various other commercial detectors, but *not* with synthetic crystals.

ÜBER DIE ELEKTRISCHE LEITFÄHIGKEIT VON NATÜRLICHEN UND KÜNSTLICHEN NaCl-KRISTALLEN (The Electrical Conductivity of Natural and Artificial NaCl Crystals).—A. D. Goldhammer. (*Zeitschr. f. Phys.*, 2nd Sept., 1929, Vol. 57, No. 3/4, pp. 173–185.)

ÜBER GLEICHSTROMVERSTÄRKUNG (The Amplification of Direct Current).—E. Rasmussen. (*Ann. der Phys.*, 15th July, 1929, Series 5, Vol. 2, No. 3, pp. 357–380.)

The writer thinks that the use of valve amplifiers

in connection with ionisation and photoelectric currents has been prejudiced by the belief that they give inconstant results and are difficult to use. Here he investigates the conditions for maximum amplification and for constancy of amplifying factor, by considering the principles governing the action of such amplifiers when used for this purpose. He concludes that they are admirable for the measurement of currents from 10^{-9} to 10^{-12} A.

THE MEASUREMENT OF SMALL DISPLACEMENTS BY PHOTOELECTRIC OR THERMOELECTRIC MEANS. —G. D. Cristescu. (*Physik. Zeitschr.*, 1st Jan., 1929, Vol. 30, No. 1, pp. 24–27.)

The body whose displacement is to be measured is connected to one of two equal optical gratings one behind the other.

AUFZEICHNUNG SCHNELLER SCHWINGUNGEN (The Recording of Rapid Vibrations).—H. Thoma. (*Zeitschr. V.D.I.*, 17th Aug., 1929, Vol. 73, No. 33, p. 1155.)

Replying to a complaint by Kurrein that in a previous paper (*ibid.*, No. 19) no mention was made of the latter's work on the study of such vibrations in machine tools, Thoma points out the great difference between results by his electrical method (modified ultra-micrometer—see October Abstracts, p. 590) and those obtained with mechanical " vibrographs." He illustrates his point with curves of the vibrations in a steam turbine taken by the two methods.

RELATIVE VISIBILITY OF LUMINOUS FLASHES FROM NEON LAMPS AND FROM INCANDESCENT LAMPS WITH AND WITHOUT RED FILTERS.—F. C. Breckenridge and J. E. Nolan. (*Bur. of Stds. Journ. of Res.*, July, 1929, Vol. 3, pp. 11–25.)

Tests undertaken to decide between various conflicting reports. The conclusions are that there is no appreciable difference in any weather-conditions between the visibility of light from a neon lamp and of light of the same colour and same horizontal candle-power distribution from an incandescent lamp. Comparing a red light from an incandescent lamp with that from the unfiltered lamp, the red filter has no effect whatever in increasing the range, in fact it reduces it: but this reduction is more than made up for by the greater ease in picking-up, in cases where the background is thickly set with other lights.

PUBLIC ADDRESS RELAYS.—(*Elec. Review*, 26th April, 1929, Vol. 104, pp. 758–759.)

An account of the recent relaying of a speech from Manchester to 29 halls in other centres in the North and Midlands. Marconi-Reisz microphones and Marconi public-address amplifiers and special loud-speakers were employed.

THE DE VRY CINETONE.—(*Journ. Scient. Instr.*, Aug., 1929, Vol. 6, pp. 262–263.)

An illustrated description of a " home talking picture " apparatus now on sale in England (*cf.* July Abstracts, p. 406). The same electric motor drives the projector (which is for 16 mm. film) and the gramophone turn-table. A special mechanism guards against film-slip, which would upset synchronisation; with the same object, the backs of the records are covered with a rough material.

FERNTAGUNGEN (Conferences at a Distance).—P. Kaspareck and R. Feldkeller. (*E.T.Z.*, 4th July, 1929, Vol. 50, pp. 997–1003.)

A description (from the Siemens and Halske Laboratories) of the cable and over-head line linking of distant Conferences carried out in Germany in 1926–1929, and a discussion of the requirements of the apparatus used for such linking.

SELECTED RADIO-TELEPHONE APPARATUS: RECENT DEVELOPMENTS AND IMPROVEMENTS.—(*Elec. Review*, 9th Aug., 1929, Vol. 105, pp. 253–254.)

Among the products mentioned is a hydro-electric battery charger for trickle-charging a l.t. battery from the water main at an expenditure of 48 galls. per hour.

KINEMATOGRAPHIE AUF RUHENDEM FILM UND MIT EXTREM HOHER BILDFREQUENZ (Kinematography on Stationary Film with Extremely High Picture-frequency).—C. Cranz and H. Schardin. (*Zeitschr. f. Phys.*, 13th July, 1929, Vol. 56, No. 3/4, pp. 147–183.)

By the methods described, the interval between pictures can be regulated from one-tenth to one three-millionth of a second; in principle, there is nothing to prevent it being reduced still further. Numerous records are shown, including some of air-waves produced by detonation and therefore travelling with more than the velocity of sound.

THE RADIO ENGINEER'S RESPONSIBILITY IN COPING WITH MAN-MADE INTERFERENCE.—E. H. Felix. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1385–1389.)

" The radio engineer must exert his influence in electrical standardisation. Instead of viewing the electrical industry as competitive and disassociated, he must work hand in hand with the appliance, power, and traction industries. The radio engineer, through his engineering association's standards committees and through the manufacturers' standardisation groups, must clearly voice his opinions, or he will find eventually that the entire burden of eliminating the effect of electrical interference will necessarily be lodged with the radio receiver itself and the transmitting system which furnishes it with programmes—at a cost to the radio industry which I have endeavoured to indicate." Such co-operation is also needed in connection with power line voltage regulation. " Little progress has been made in this direction up to this time."

RADIO COORDINATION.—M. D. Hooven. (*Proc. Inst. Rad. Eng.*, Aug., 1929, Vol. 17, pp. 1390–1394.)

Another article on man-made interference, in which the work of the American Committee on

Inductive Coordination is referred to. Reference to its Serial Report, Aug. 1927 ("Radio Coordination") is recommended.

RUNDFUNKSTÖRUNGEN DURCH ÜBERLAGERUNGSGERÄTE (Disturbance of Broadcast Reception by Heterodyne Apparatus).—F. Vilbig. (*T.F.T.*, July, 1929, Vol. 18, pp. 217–223.)

An investigation by the German P.O. engineers into the effects of heterodyne receivers in interfering with other receivers. The conclusions are as follows:—to avoid radiating into the aerial, a preliminary valve is recommended. As a rule, however, the choice of a suitable intermediate frequency and the use of as little ohmic resistance as possible is enough to prevent trouble. The coupling condenser between the first and second circuits should also be kept small.

MINERALQUELLEN ALS URSACHE VON RUNDFUNKSTÖRUNGEN (Mineral Springs as Cause of Interference with the Reception of Broadcasting). (*R., B., F. f. Alle*, September, 1929, p. 415.)

At Wiesbaden, interference with broadcast reception occurring regularly just after sunset, and hitherto attributed to atmospherics, is now said to be due to the radio-active mineral springs under the town.

VIOLET AND ULTRA-VIOLET HOT-CATHODE TUBES. (French Patent 657936, Philips' Co., pub. 29th May, 1929.)

A special discharge tube (mercury vapour and rare gas, in glass) with auxiliary anode for starting up and an internal co-axial quartz tube for leading out the required rays.

A MACHINE TO DEMONSTRATE THE PROCESS OF MODULATING A CARRIER WAVE.—A. C. Timmis. (*P.O. Elec. Eng. Journ.*, July, 1929, Vol. 22, pp. 128–130.)

AN ACCELEROMETER UTILISING PIEZO-ELECTRICITY.—K. Yamaguchi. (*Bull. Inst. Phys. Chem. Res.*, No. 3, 1929, Vol. 8, pp. 164–179.)

In Japanese. The forces of acceleration produce piezoelectric charges which after amplification are recorded in an oscillograph.

THE ELECTRIC POLARISATION IN INSULATORS PRODUCED BY ACCELERATION.—E. Brody. (*Zeitschr. f. Phys.*, Jan., 1929, Vol. 52. No. 11/12, pp. 884–889.)

A theoretical consideration of the possible electric polarisation of a crystal, containing negative and positive ions of different masses, on being subjected to acceleration.

FRICTIONAL ELECTRICITY.—W. Kluge. L. Wolf. (*Ann. der Phys.*, 2nd and 19th January, 1929, Vol. 1, Nos. 1 and 2, pp. 1–39 and 260–288.)

In both sets of experiments the conditions were made as definite as possible so as to make the results consistent and reproducible. The first writer studies the effect of various degrees of vacuum; the second discusses his results in terms of the "solution pressure" theory.

ÉLECTROLYSE DE L'EAU EN COURANT ALTERNATIF (Electrolysis of Water by Alternating Current).—A. Canaud. (*Comptes Rendus*, 27th May, 1929, Vol. 188, pp. 1397–1398.)

SUR UN PROCÉDÉ DE PHOTOMÉTRIE PHOTOÉLECTRIQUE AVEC SOURCE DE RAYONNEMENT VARIABLE (A Photoelectric Photometry Process for Variable Sources of Radiation).—T. D. Gheorghiu. (*Comptes Rendus*, 17th June, 1929, Vol. 188, pp. 1609–1611.)

Usually, for variable sources of radiation, two photoelectric cells in opposition are employed. This involves certain difficulties (*e.g.*, "matching" the cells) and the writer has designed an arrangement avoiding these difficulties and giving results as accurate as those obtainable with a constant source. He uses two cells, each connected to a separate electrometer. The method is described and several advantages enumerated.

PROCÉDÉ D'EXPLORATION ÉLECTRIQUE DU SOL AU MOYEN DE COURANTS ALTERNATIFS À FRÉQUENCE EXTRÊMEMENT BASSE (Process of Electrical Exploration of the Soil by means of a.c. of extremely low Frequency).——. Ambroun. (*Génie Civil*, 10th August, 1929, Vol. 95, p. 144.)

The French patent (652418) deals with the use of frequencies varying from 0.3 to 10 p.p.s., the distribution of the fields being found without the use of non-polarisable electrodes. The indicating instrument may be electromagnetic, tuned to the low a.c. frequency, or of another type; before reaching the instrument, the slow a.c. component is filtered free from the d.c. component due to natural earth currents or to electrochemical action at the electrodes.

APPLIED GEOPHYSICS IN THE SEARCH FOR MINERALS.—A. S. Eve and D. A. Keys. (*Engineer*, 23rd Aug., 1929, Vol. 148, p. 201.)

A rather long review of the book recently published under this title—the "first British book on the subject."

ELECTRICAL METHODS OF PROSPECTING.—F. Vercelli. (*Accad. Lincei, Atti*, 11th Nov., 1928, Vol. 8, pp. 342–347.)

The use of armoured cable to connect generator and field instruments considerably reduces disturbance and interference, and has other advantages.

SOUNDING AND DISTANCE-MEASUREMENT BY VERY SHORT WAVE-TRAINS. (French Patent 650129, Warluzel, pub. 4th Jan., 1929.)

The echo, which on its return finds the generating wave-train completely extinguished, acts on a monotone receiver (*e.g.* tuned diaphragm). The time between signal and echo is measured by a hot-wire movement, in which the deflection of a pointer is proportional to the time during which the current is allowed to flow through the wire.

ICEBERG DETECTION.—H. T. Barnes. (*Nature*, 31st Aug., 1929, Vol. 124, p. 337.)

A cable announcing that one of the results of the Van Horne Expedition, just returned from iceberg study on the Atlantic, was the reception of very loud deep noises from an iceberg three miles away, by the submarine microphone detector. These noises (which became faint at six miles) are apparently due to the cracking under water of the iceberg, and they could readily be heard above the usual ship's noises. The succession of cracks was irregular, varying from 11 to 68 a minute. "The effect is so characteristic that we propose to extend the investigation in the hope of finding a method of iceberg detection."

ANALYSER FOR RESEARCH ON ACOUSTIC ALTITUDE MEASUREMENT FOR AIRCRAFT. — L. P. Delsasso. (*See* under "Acoustics.")

AUTOMATISCHE STEUERUNG VON AUFZÜGEN MIT HILFE VON ELEKTRONENRÖHREN (Automatic Control of Lifts by the use of Thermionic Valves).—*Elektrot. u. Masch : bau*, 14th July, 1929, Vol. 47, p. 607.)

The writer of this paragraph, on a paper by W. O. Lum, mentions that the same idea (the formation or screening of a reaction coupling of a valve circuit when the moving body reaches a certain position) has been used for switch-control on the Berlin Express Postal tube.

CLOCK SETTING BY WIRELESS AUTOMATIC SYNCHRONISATION FROM TIME SIGNALS.—(*Wireless World*, 14th Aug., 1929, Vol. 25, pp. 145–146.)

An illustrated description of the apparatus employed to make use of the clock-setting signals from Radio-Paris.

REMISE À L'HEURE DES HORLOGES ET COMMANDES À DISTANCES DIVERSES PAR LES LIGNES TÉLÉPHONIQUES (Clock-setting and Various Distant-controls by Telephone Lines).— —. Lavet. (*Bull. d.l. Soc. Franç. d. Élec.*, June, 1929, Vol. 9, pp. 639–646.)

THEORY OF THE DEION CIRCUIT BREAKER.—J. S. Slepian and others. (*Journ. Am. I.E.E.*, Feb., 1929, Vol. 48, pp. 93–104.)

The breaker here dealt with consists of a stack of copper plates separated by insulating spacers which breaks up the arc (blown by a magnetic field on to the stack) into a large number of small arcs in series: at the current zero each cathode layer is almost instantly deionised. See also June Abstracts, p. 347.

DAS SCHALTEN GROSSER LEISTUNGEN (High Power Switching).—F. Kesselring. (*E.T.Z.*, 11th July, 1929, Vol. 50, pp. 1005–1013.)

After a theoretical discussion of the problems of switching large amounts of power, the paper deals with new types of switches for this purpose, including the Deion circuit breaker referred to in June Abstracts, p. 347, and above.

STUDY OF NOISES IN ELECTRICAL APPARATUS.—T. Spooner and J. P. Foltz. (*See* under "Acoustics.")

ELECTROMAGNETIC TESTING FOR MECHANICAL FLAWS IN STEEL WIRE ROPES.—T. F. Wall. (*Journ. I.E.E.*, July, 1929, Vol. 67, pp. 899–911.)

SIGNALLING BY ULTRA-VIOLET RADIATION.—Y. Rocard. (*Rev. d'Optique*, January, 1929, Vol. 8, pp. 9–15.)

DOES NATURAL IONIZING RADIATION CONTROL RATE OF MUTATION ?—E. B. Babcock and J. L. Collins. (*Proc. Nat. Acad. Sci.*, 15th Aug., 1929, Vol. 15, pp. 623–628.)

The full paper on the researches referred to in October Abstracts, p. 589.

THE GENERATION OF ELECTRIC POWER FROM ENERGY IN UNFROZEN WATER UNDER SURFACE ICE.—H. Barjot. (*World Power*, Sept., 1929, Vol. 12, pp. 217–220.)

An illustrated expansion of Barjot's *Génie Civil* paper (April Abstracts, p. 228.)

ON THE EFFICIENT UTILISATION OF SOLAR ENERGY.—R. H. Goddard. (*Journ. Opt. Soc. Am.*, July, 1929, Vol. 19. pp. 42–46.)

After stating the conditions to be satisfied by an ideal solar engine, the writer describes his "vaporizer" (patented recently) and examines it to show how well it conforms with these conditions. An interesting feature is the extreme lightness for a given power, resulting from the small size, the possibility of using light materials, and the absence of the weight of fuel.

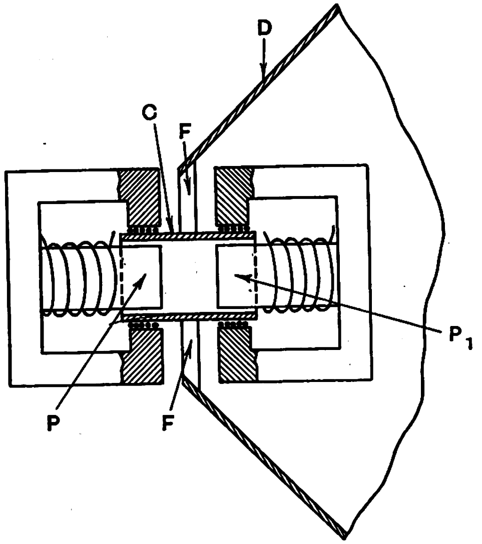
Some Recent Patents.

The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

LOUD SPEAKERS.

Application date, 1st February and 22nd March, 1928. No. 312950.

The moving coil *C* is mounted to vibrate in the gap between two adjacent pot-magnets *P*, P_1.



No. 312950.

The windings on the coil are divided into two sections connected in series. The cone diaphragm *D* is connected to the moving-coil element by radial arms *F* extending outwards through the space between the adjacent magnets.

Patent issued to O. D. Lucas.

TELEVISION SYSTEMS.

Convention date (U.S.A.), 22nd June, 1927. No. 292546.

The quality of the image current sent out from a television transmitter is supervised or "monitored" at the transmitting end by tapping-off a portion of the outgoing current and diverting it back to the scanning disc used for transmission. The latter therefore serves simultaneously for re-assembling the monitoring currents and projecting them in proper sequence upon a local viewing screen. The aperture employed for monitoring is separated on the scanning disc by 90° from that used for modulating the outgoing current, so as to prevent interference.

Patent issued to Electrical Research Products, Inc.

INDIRECTLY-HEATED VALVES.

Convention date (Germany), 25th June, 1927. No. 292913.

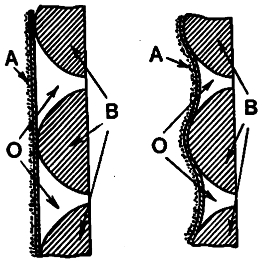
The ends of the filament are wound into open-ended coils, which are then heated by electronic bombardment from an A.C. supply and so raise the intermediate wire or filament to the required temperature by positive conduction from both ends. The rectifying action of the electronic bombardment may simultaneously be utilised, in combination with suitable filter circuits, to supply both the plate voltage and the direct current for operating subsequent stages of L.F. power amplifiers. It may also be used for energising the field magnets of a moving-coil loud-speaker.

Patent issued to S. Loewe.

ELECTROSTATIC LOUD SPEAKERS.

Convention date (Germany), 29th December, 1927. No. 303131.

The rigid conducting plate *B* of an electrostatic loud speaker is formed with a series of holes *O*, the bounding surfaces of which are parabolic in section as shown enlarged in the Figure. The vibrative membrane *A* consists of a rubber sheet with a thin layer of conducting material, such as carbon particles or metal foil. Owing to the shape of the curved portions of the plate *B*, the electrostatic field between the two surfaces remains constant over a large amplitude of vibration of the membrane *A*, thereby maintaining a proportional response over a wide range of input energy.



No. 303131.

Patent issued to E. Reisz.

GRAMOPHONE PICK-UPS.

Convention date (U.S.A.), 5th November, 1927. No. 300115.

The component parts of the pick-up are mounted on a base plate which lies in a plane substantially parallel with that of the gramophone record. The base plate is provided with an inclined platform to take the magnetic pole-pieces, between which the armature is placed in such a way that it can vibrate freely in a plane passing through the longitudinal axis of the base plate without the provision of end pivots or trunnions.

Patent issued to Federal Telegraph Co.

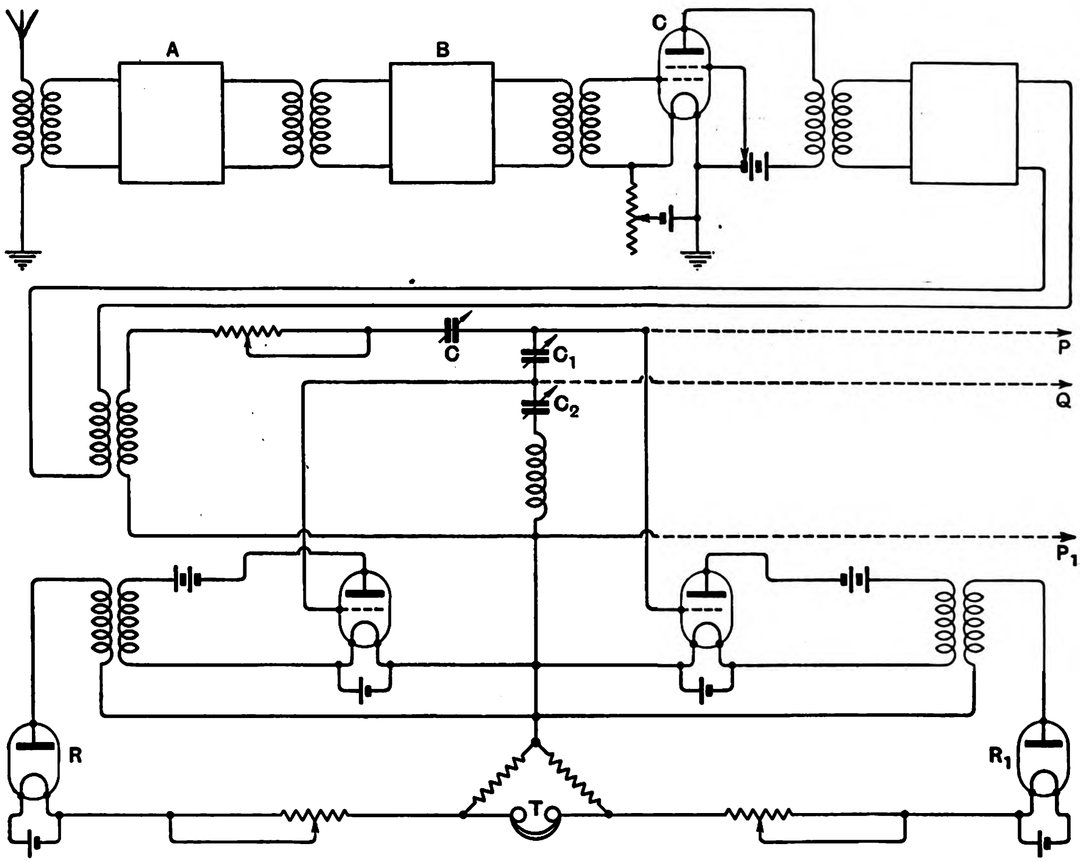
COMPENSATING FOR FADING.

Convention date (*U.S.A.*), 18*th May*, 1927. *No.* 290642.

Relates to means for overcoming the effect of rapid changes in the transmission efficiency of the ether as distinct from slow fading fluctuations. The signals are transmitted in the form of a frequency-modulated carrier wave. At the receiving end two branch circuits are used and are so arranged that changes in amplitude of the received signal induce substantially equal voltages, whilst changes in frequency (*i.e.*, signal currents) induce unequal voltages.

As shown the incoming signals are passed through a band filter A, are amplified at B, and passed through a limiter valve C, which removes any outstanding amplitude variations. The resulting frequency-modulated carrier is then passed to the network of impedances shown, the variable condensers C, C_1, C_2 being so adjusted that the circuit between P and P_1 is non-reactive for the highest frequency of the transmitted band, whilst the circuit between Q and P_1 is non-reactive for the lowest frequency. For intermediate (signal) frequencies the reaction (induced voltage) varies in proportion to the frequency. Any amplitude-variations will induce equal but out-of-phase voltages across P, P_1 and QP_1, which balance out across the rectifiers R, R_1 and phones T. Frequency variations across the circuits P, P_1 and QP_1, however, produce a cumulative effect in the phones, and so reproduce the original signal. Since static as well as rapid fading is usually manifested as amplitude variations, both effects are largely eliminated.

Patent issued to E. H. Armstrong.



No. 290642.

TOROID COILS.

Convention date (*U.S.A.*), 11*th August*, 1927. *No.* 295395.

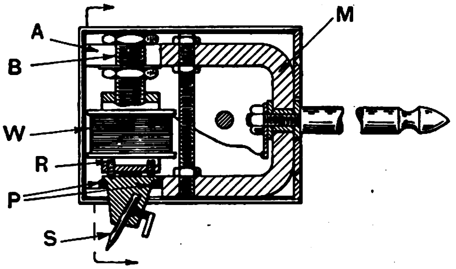
A basket coil is first wound on a former consisting of a circular series of hollow tubes of flexible material stiffened by the insertion of iron rods. As soon as a sufficient length of cylindrical basket-winding has been formed, the metal rods are withdrawn from the formers, and the whole winding is then bent around until the two ends meet. The ends are clamped in a suitable socket to form a closed toroid coil.

Patent issued to J. S. Lottrup.

GRAMOPHONE PICK-UPS.

Application date, 24*th May*, 1928. *No.* 314648.

The upper limb of the usual magnet M is slotted at A to take the screwed stem B of a U-shaped



No. 314648.

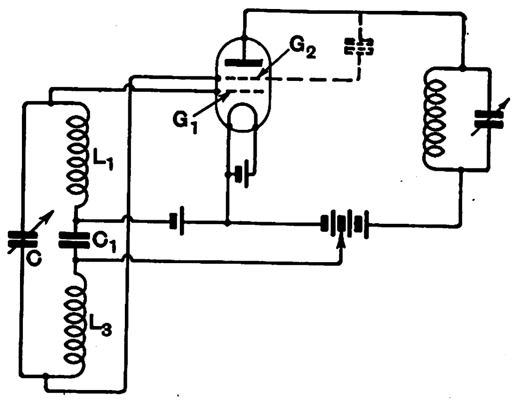
yoke carrying a pair of pole windings W. The yoke is adjustably mounted by means of the lock-nuts shown. The lower limb of the magnet M is also slotted to accommodate the armature R and the stylus holder, which together form a T-shaped piece extending under both pole-pieces. The point of the stylus is arranged to be on a vertical line passing through the axis of oscillation of the armature as a whole. A pad P of rubber or other resilient material is interposed between the lower surface of the magnet limb and the underside of the armature as shown. By adjusting the lock-nuts holding the yoke in the upper slot A of the magnet, any desired degree of clamping between the armature and the pad P can be secured.

Patent issued to The Electramonic Co., Ltd., S. J. Tyrrell, D. W. Sayers, and L. N. Tyrrell.

STABILIZING CIRCUITS.

Application date 30*th March*, 1928. *No.* 314921.

Relates to four-electrode amplifiers comprising an inner or control grid G_1 and an outer grid G_2 carrying a positive bias. Although the presence of the grid G_2 reduces the inter-electrode capacity



No. 314921.

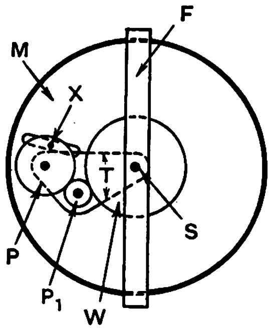
coupling between the plate and the control grid G_1, there is a residual capacity effect, which, according to the invention, is eliminated by applying a compensating voltage to the grid G_2 by means of a coil L_3 in series with the input coil L_1. The two coils are separated by a blocking condenser C_1, the tuning condenser C being shunted across both coils.

Patent issued to E. C. R. Marks.

DIRECTION FINDING.

Application date, 7*th July*, 1928. *No.* 315990.

Quadrantal error, arising from the presence of conducting bodies in close proximity to a directional receiving aerial, is automatically compensated by means of a moving scale actuated by gearing from the aerial shaft. Fixed to the shaft S of the frame aerial F is a triangular bracket T carrying pinions P, P_1, the latter meshing with a gear-wheel W fixed rigidly to the framework of the apparatus. A pin X adjustable radially on the pinion P engages with a slot formed in the calibrated scale-disc M. As the frame aerial is rotated into alignment



No. 315990.

with a given station, the eccentric action of the pin X in the slot imparts an independent forward or backward rotation to the disc M sufficient to compensate automatically for the degree of quadrantal error involved.

Patent issued to Radio-Communication Co., Ltd., and F. P. Best.

DRY-CONTACT RECTIFIERS.

Convention date (*Germany*), 27*th January*, 1928. *No.* 304748.

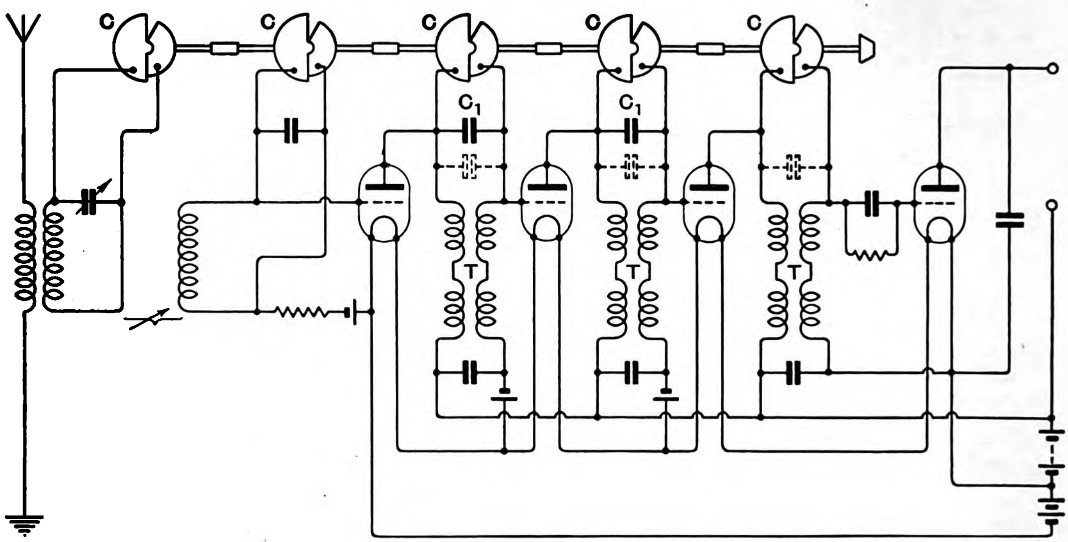
An electrode for contact rectifiers in which the rectifying action depends upon the presence of a sulphur, selenium, or tellurium compound of copper is made by inserting in a high-powered press a layer of pulverised copper, followed by a layer of cupric sulphide in the proportions of two to one. The mass is subjected to a pressure of several thousand kilogrammes per square centimetre. When it coheres a counter-electrode of aluminium or magnesium is applied, under a lesser pressure, to complete the rectifying unit.

Patent issued to Siemens Schuckertwerke A.G.

SELECTIVE "BAND" AMPLIFIER.

Application date, 3rd *January*, 1928. *No.* 314884.

The input circuit and intervalve couplings are designed to accept and amplify a band of frequencies corresponding to the carrier-wave and modulation side-bands of a Broadcast programme.



No. 314884.

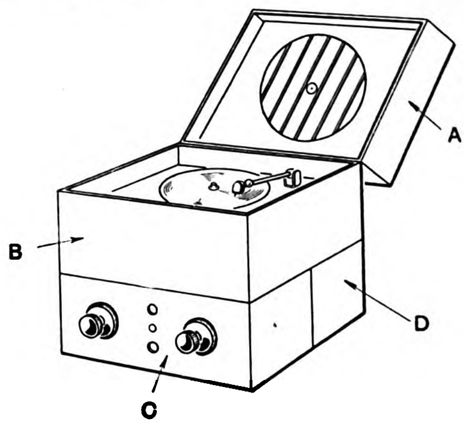
The response is uniform over a definite narrow band of frequencies, all frequencies lying above and below this band being substantially rejected. This ensures high selectivity without any distortion due to the loss of the essential side-band components. Preferably the central or "peak" frequency of each stage or amplification differs slightly from stage to stage, the respective outputs being combined to ensure a uniform overall amplification within the desired limits. The necessary tuning-characteristics of the coupling-transformers *T* may be ensured by varying the number of turns in the primary and secondary windings, or by varying the inherent capacity between the windings. Additional reactances such as the condensers *C* may also be added at each stage. Tuning up and down the frequency scale is effected by means of condensers *C* ganged together on a common control spindle.

Patent issued to E. C. R. Marks.

COMBINATION SETS.

Application date, 11*th June*, 1928. *No.* 314660.

A compact portable installation, designed for Broadcast reception or for amplified gramophone reproduction, comprises a mains-eliminator unit and an electric driving-motor for the gramophone disc, the necessary electrical connections being automatically made as the unit is assembled. As shown diagrammatically, a cone loud-speaker is housed in the lid *A*, the output leads passing through the hinges. The gramophone and driving motor are housed in a unit *B* which is fitted by plug-and-socket connections to a two-part base, the front portion *C* of which forms the radio receiver and amplifier, and the rear part *D* a mains eliminator unit. The connections are made through



No. 314660.

plug-and-socket fastenings holding the whole assembly together.

Patent issued to British Thomson-Houston Co., Ltd., A. P. Young and J. H. Butcher.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. VI. DECEMBER, 1929. No. 75.

Editorial.

The Losses in Air Condensers.

ON p. 656 of this number we publish a paper by Mr. Wilmotte in which he describes a method of measuring the losses in air condensers and gives examples of the results obtained in some actual tests. The method itself is the well-known one in which a current is induced in a tuned circuit containing the condenser under test which is then replaced by a standard condenser, in which the losses are small and known, in series with a resistance which is varied until the combination is exactly equivalent to the condenser under test, as indicated on a thermal ammeter in the tuned circuit. Those who have tried to carry out this measurement at high frequencies will know how difficult it is to obtain consistent and reliable results, and will appreciate the useful hints which the author gives and the description of the special apparatus devised for the purpose of the test. The method has been used for frequencies up to 6×10^6 ($\lambda = 50$ metres); at these frequencies, unless special precautions are taken, it is easy to obtain results which are so inaccurate as to be entirely worthless.

Mr. Wilmotte's analysis of his results is expressed by what he calls an empirical formula, but we doubt if the adjective is quite justifiable. We may assume that the losses in an air condenser are made up of two parts, one due to the resistance of the leads, connections, plates, etc., and the other due to losses in the solid dielectric material situated in the electric field. The former may be regarded as a series resistance, probably variable to a slight extent with frequency; the latter may be regarded as due to a solid dielectric condenser in parallel with the air condenser. If we assume that the loss W due to hysteresis in the solid dielectric is proportional to the frequency and to the square of the voltage, we may write $W = a\omega V^2$, where a is a constant. The condenser current $I = \omega CV$ to a high degree of approximation, and for an equivalent series resistance R to give the same loss of power as the solid dielectric we must have

$$I^2R = W = a\omega V^2$$

and $$R = \frac{a\omega V^2}{I^2} = \frac{a\omega V^2}{\omega^2C^2V^2} = \frac{a}{\omega C^2}.$$

The total apparent series resistance will therefore be

$$r + R = r + \frac{a}{\omega C^2},$$

where a is a constant and r probably varies but little over a wide range of frequency. This is exactly the result obtained by Mr. Wilmotte from his tests, which therefore serve to confirm the above assumptions. One disadvantage of the method is the necessity of having a standard condenser for comparison, the losses in which must be small and known. The National Physical Laboratory is, of course, well provided in this respect, but Mr. Wilmotte does not state what condenser he used for the purpose nor what assumptions were made as to its losses

G. W. O. H.

The Comparison of the Power Factors of Condensers.

By Raymond M. Wilmotte, B.A., A.M.I.E.E.

Introduction.

THE usual method of comparing the power factors of two condensers at radio frequencies is to measure the resistance of a circuit containing one of the condensers, then to substitute the other condenser for the first and again measure the resistance of the circuit. The difference between the two readings gives the difference between the effective series resistances of the two condensers.

Those who have employed such methods will know how tedious the measurements are. When the two condensers are of similar quality, many of the errors inherent in the usual methods of resistance measurements do not appear, as they cancel one another, but, when bad dielectrics are being measured, this is by no means the case and the most difficult cause of error to overcome, namely, reaction back from the circuit being measured on to the source of high-frequency power still remains.

It was in order to see to what extent a simple substitution method could simplify the usual method of measurement that the apparatus described in this article was developed. The degree of accuracy reached was considerably superior to that anticipated. Moreover, much higher frequencies than are suitable for the ordinary method have been found to be workable. The upper frequency limit of the method is not known. The highest frequency used has been 6,000 kilocycles, but there is no reason to suppose that still higher frequencies could not be used.

The principle of the method is very simple; it consists of tuning a circuit with each condenser separately and rapidly switching from one to the other. A resistance is inserted in series so that the current is brought to the same value in the two cases. The value of the resistance will then be the difference between the effective series resistance of the two condensers. One of the condensers is usually a standard the power factor of which is either known or else negligibly small.

Design of Continuously Variable Resistance.

An essential instrument for the application of the method is a continuously variable resistance suitable for high frequencies. This instrument will not be described in detail as this was done in a previous number of the *E.W. & W.E.* ("A variable resistance suitable for high frequencies," by R. M. Wilmotte, *E.W. & W.E.*, Vol. 2, 1925, pp. 684–686). Since this instrument was designed a few alterations have been made. The variation of resistance is obtained by making part of the wire of copper and part of eureka. The brushes are kept fixed and the wire moved so that when the pointer is at zero the wire between the brushes is nearly all copper, and when it is at full scale (1.1 ohms) the wire is nearly all eureka. In this way the shape and position of the electric circuit remains absolutely unaltered. The real difficulty in the design is to prevent too large a variation of resistance occurring with frequency. For this it is essential that the wire be very thin or that thin strips be used. Actually, the thickness of the strips used was 0.05 mm. When such thin strip is used it is difficult to allow the brushes to make contact with much pressure without fouling the strip, so that normally the contact resistance is large and variable. In order to overcome this difficulty, in the first design the contact was moistened with oil, but this was not found completely satisfactory and the contacts are now kept permanently under oil. A further difficulty arose after the resistance had not been used for several weeks, the contact was found to be bad owing to the wire having been attacked by the sulphur contained in the oil and in the ebonite, of which the instrument was made. This was satisfactorily overcome by making the instrument wholly of bakelite and using medicinal paraffin for the oil. Even now it is advisable to vary

the resistance backwards and forwards a few times before using, so as to thoroughly oil the whole wire and remove any impurity from its surface by means of the brush friction. In Fig. 1 is shown the measured variation of resistance with frequency. This has been measured up to a frequency of 12,000 kilocycles.

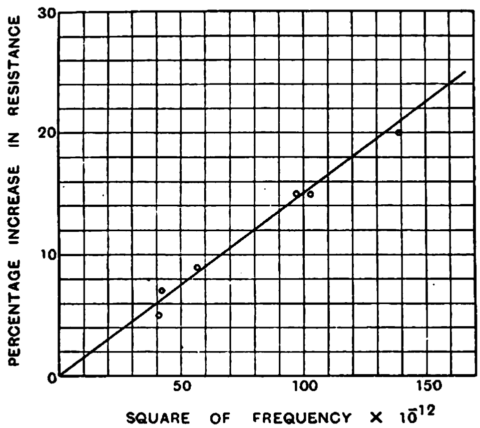


Fig. 1.

The resistances as described here have now been in use at intervals for over a year and have been found satisfactory.

The Complete Apparatus.

The complete circuit is shown diagrammatically in Fig. 2. The high-frequency E.M.F. is induced in a convenient coil L. Actually L consists of two coils in series, which can be adjusted relatively to each other to give a variable self-inductance. A number of flat coils have been designed for this purpose. The coil is connected through a reversing switch Q to either of the condensers C_1 or C_2 which are being compared, *via* the leads A and B and the key S. The design of this key will be considered below. In series with the condensers, are two variable resistances R_1 and R_2 of the type already described. In order to permit differences of resistance greater than 2 ohms, mercury cups are put in series with the continuously variable resistances, and in these cups may be inserted fixed resistances, made of very fine (No. 47 s.w.g.) resistance wire. The current is measured by means of a thermo-junction non-contact ammeter T of the type recently described by F. M. Colebrook and the author (*E.W. & W.E.*, Vol. 5, 1928, pp. 538–544) connected to a galvanometer G. The use of the potentiometer P and the condenser C_0 will be considered later.

The procedure is to tune the circuit first with the point 2 of the key S connected to the point 1 and, secondly, with the point 2 connected to the point 3. The resistances R_1 and R_2 are adjusted until the same current flows in the thermo-ammeter T for both positions of the key S.

In order that consistent and correct results may be obtained by such a method, it is essential that the E.M.F. induced in the circuits corresponding to the two positions of the switch S should be accurately equal. That is, the two circuits should be as electrically similar as possible. For this reason everything possible should be screened. The leads A and B are screened by each other, the lead B being a tube surrounding the wire A. These two leads are made as long as is conveniently possible (in the actual apparatus they are about 3 ft.), so that the E.M.F. induced from the source into the critical portions of the circuit beyond the thermo-ammeter T might be as small as possible. This critical portion of the circuit from the thermo-ammeter T to the condensers C_1 and C_2 is unscreened. This part of the circuit is kept as small and as

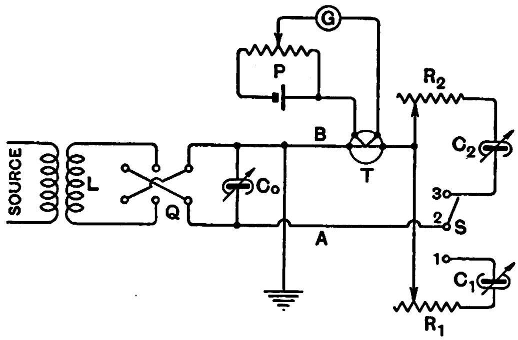


Fig. 2.

close together as possible. It was not found necessary to screen the resistances R_1 and R_2 because they were on the low-tension side of the circuit being connected to the screens of the condensers and to the earth lead B. It is necessary, however, to have both condensers C_1 and C_2 screened.

In order to eliminate any small difference

in E.M.F. between the two circuits that may be induced in the part beyond the switch S, the main E.M.F. induced in the circuit is reversed by means of the reversing switch Q. The tuning will have to be readjusted and a small change will occasionally be found to be necessary in the adjustment of the resistances R_1 and R_2. This precaution is unnecessary except for very accurate work.

It will be noted—and this is essential to the success of the method—that the screens of the condensers are permanently connected together through very low impedances (the resistances R_1 and R_2) so that any current to earth *via* the screen will be constant for both positions of the key S. The only earth current that may vary is that from high-potential leads going from the key S to the insulated terminals of the condensers. These are very short (about 6 in. long), but were the cause of some trouble. For a considerable time there was an unknown source of loss in one of the circuits. It was very small (of the order of 0.02 ohm), but still always present. It was finally found to be due to dielectric losses in the wood in the neighbourhood of the high-potential leads from the switch to the condensers. This source of error was removed by screening the wood from the leads and connecting this screen to the common terminal of the resistances R_1 and R_2.

Another source of error which is liable to occur in the setting of the apparatus is due to the screens of the condensers C_1 and C_2 being in contact with each other either by touching directly or through the bench on which the apparatus is set up. A closed circuit is thereby formed in which there is a bad contact, which causes some trouble and errors in the measurements.

The accuracy of the methods largely depends on the accuracy of tuning the circuits, and everything should be done that this may be sharp. It is, therefore, a great help to have variable condensers with easy adjustments. The standard condenser should be fitted with some form of reduction gear, such as a worm drive, but this is not always available on the condenser under test, which, incidentally, may be a fixed condenser. The tuning in such cases is carried out (for the circuit with the condenser under test) at first roughly by means of the coil L and finally with the screened condenser C_0 fitted with a worm drive. This condenser, being always in circuit, need not have a particularly good power factor. The circuit standard condenser is tuned in the ordinary way. An error may here occur owing to the different manner of tuning the two circuits. In one case the condenser, which is varied, lies between the thermo-ammeter and the coil, while in the other it lies on the other side of the thermo-ammeter. The difference will always be very small unless the tuning is very blunt (if, for instance, the capacity of the condensers under test is very large), but it is nevertheless advisable to keep the value of C_0 smaller than that of the condensers under test. If the thermo-ammeter T were placed immediately after the switch Q and before the condenser C_0, this error would not occur. This mode of connection was not tried and would no doubt be satisfactory, but the apparatus having been found to be amply suitable, it was not considered worth while to alter it. There is something to be said in favour of putting the thermo-ammeter immediately after the switch Q, for although the existence of C_0 would not affect the sensitivity compared with that of the arrangement described (Fig. 2), yet a greater current could be obtained for a smaller coupling with the source. In either position of the thermo-ammeter the condenser C_0 reduces the sensitivity approximately in the ratio of

$$\frac{C_1^2}{(C_0 + C_1)^2}$$

where C_1 is the value of the capacity under test.

On the score of sensitivity, therefore, it is also advantageous to keep the value of the condenser C_0 as small as is conveniently possible.

A thermo-ammeter is a square-law instrument. This means that a small change in the current will produce a change in the deflection which is proportional to the value of the current. Hence the greater the current in the ammeter the greater the sensitivity of the method. It is possible to pass a current up to the full carrying capacity of the instrument by tightening the coupling of the coil L to the surface, but the galvanometer will then be deflected off the scale. In order to bring it back into the scale, a potentiometer arrangement P is inserted

in the galvanometer lead producing a potential difference in opposition to the E.M.F. in the thermo-junction of the ammeter. In this way it is possible to use a very sensitive galvanometer and still pass a large current in the ammeter. The coupling of the source of the coil L can be made much tighter than in ordinary methods because reaction back on to the source produces no error, but it must not be made so tight that the source becomes unstable at some frequency, for it then becomes impossible to tune the circuits.

To facilitate working it is important that the contact resistance at the key S should be as perfect as possible and that its motion should be rapid. The advantage of a rapid motion is that the galvanometer has not time to move appreciably while switching over, and measurements can be carried out far more rapidly. Originally a simple mercury switch was used, but it was found too slow and a mechanical key of special design has now been substituted.

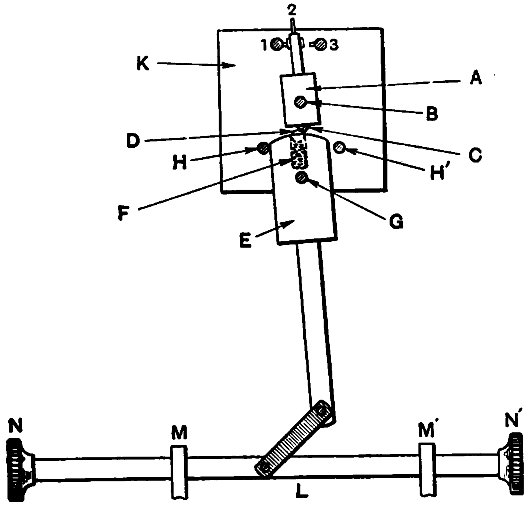


Fig. 3.

The design of this key, due to Mr. Murfitt, is shown in Fig. 3. It is entirely made of ebonite except for the shaded portions which are of brass or copper. The contacts 1, 2 and 3 have small lengths of platinum wire brazed on them so as to ensure low contact resistance. The moving contact 2 is screwed into a small ebonite block A pivoted at B. At the other end of the block B there is a brass wedge C against which presses a ball D. This ball is held within another ebonite block E and kept pressed against the wedge C by means of the spring F; the ebonite block E is pivoted at G and its motion is limited by means of two stops H and H'. The contacts 1 and 3, the pivots B and G and the stops H and H' are all fixed into a square ebonite support K. The key is worked by means of links from the ebonite rod L moving in guides M and M'. There are two knobs N and N' shown, so that the key can be worked from either side.

It will be seen that the contact 2 will not start to move until the ball D has been forced past the edge of the wedge C. As soon as this is reached the contact will rapidly move to its other position. In this way a very rapid motion is obtained which facilitates and quickens very considerably the working of the method. The contact pressure and the rapidity of the motion largely depend on the strength of the spring F.

The link mechanism for working the key is very useful, in that it allows the observer to move the switch without his hand approaching any high-potential wires. This is particularly important at very high frequencies, when any motion of the observer may alter the tuning.

Precautions and Advantages.

It may be useful to summarise the precautions necessary in order to obtain reliable results with this method.

These are :—

(1) That the condensers under test should be screened.

(2) That the screens of the condensers under test should not touch. The condensers are best placed on blocks of paraffin wax.

(3) That the condensers under test should be connected to the apparatus by short thick copper leads as nearly equal for the two condensers as possible.

(4) That the observer and other neighbouring objects should not alter their positions during a measurement otherwise the tuning may be affected, especially at high frequencies. Tuning is made easier by earthing the outside of the long concentric lead.

(5) That the condenser C_0 be kept small.

(6) For very accurate work the switch Q should be reversed, the tuning readjusted and the mean of the resistance readings taken. It will be found that both tunings can be readjusted with condenser C_0 alone.

(7) For sensitivity the current in the ammeter should be as large as possible, the galvanometer as sensitive as possible, and the coil L as low in resistance as possible.

The advantages claimed for the method compared with the ordinary methods at present in use are:

(1) Increased sensitiveness.

(2) Elimination of error from reaction back on to the source (particularly when a bad condenser or dielectric is being measured).

(3) Suitability for measurement at much higher frequencies.

(4) Greatly increased rapidity and ease of working.

The experimental evidence for the reliability of the method is very simple. If there is a difference of E.M.F. induced in the two circuits, different results should be obtained if the condensers be interchanged. This has been tried a very large number of times using many types of condensers, at frequencies varying from 50 kilocycles to 5,000 kilocycles, but when differences have been obtained they have always been found to be caused by some inattention to the precautions detailed above. The effect of earthing the long screened lead was also tested in the same way but no difference was ever found.

Experimental Results.

Tests on two variable air condensers will be given here. The losses in a condenser are due first to the loss in the dielectric and secondly to the ohmic loss of the current flowing in the connections and plates of the condenser. The dielectric loss will be proportional to the square of the voltage across the condenser, unless the voltage is so high as to be approaching the breaking stress of the insulation, while the ohmic loss will be proportional to the square of the current. Both will depend to a certain extent on the frequency, but at any given frequency they should be independent of the condenser setting. At any given frequency, therefore, the losses in a variable condenser should be amenable to representation by means of a

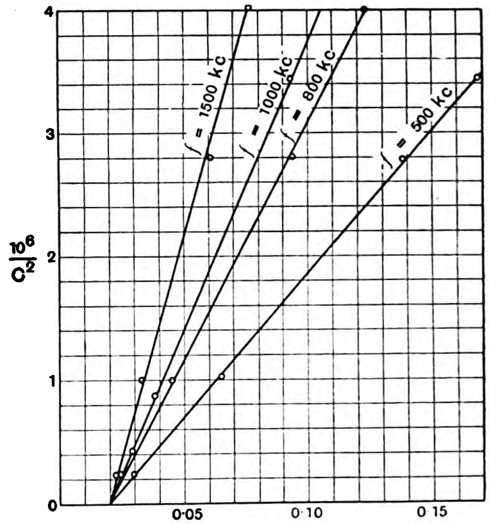


Fig. 4.

fixed series resistance to represent the ohmic loss, together with a fixed shunt resistance to represent the dielectric loss. With alteration of frequency the change in the series resistance should be very small, but that in the shunt resistance may be expected to be very appreciable. This representation of dielectric loss by means of a constant shunt resistance at a given frequency depends on the assumption that the distribution of electric lines of force remains unaltered within that part of the dielectric which is causing loss, as the condenser setting is varied. This condition is likely to exist in variable air condensers (free from dust), for the portion of the dielectric which produces losses is usually at a comparatively large distance from the moving plates. If, however, the losses in the air dielectric between the plates are not negligible, it is not likely that a constant shunt resistance would satisfactorily represent the dielectric losses at any given frequency.

A constant shunt resistance can be represented by a variable series resistance the value of which varies inversely as the square of the capacity of the condenser at any

given frequency. If the losses of a variable condenser can be represented by means of a constant series and a constant shunt resistance at any given frequency, the total equivalent resistance at this frequency should, therefore, consist of two terms, one of which is constant and the other which varies inversely as the square of the capacity of the condenser.

In Figs. 4, 5 and 6 are shown the results on two condensers. In order to investigate the truth of the above statements, the equivalent series resistance was plotted against the reciprocal of the square of the capacity. In every case tested, and many have been tested besides those shown here, straight lines have been obtained. These lines do not pass through the origin, and the intercept on the abscissa no doubt corresponds to the series resistance due to internal leads and conduction over the plates of the condenser. This is all the more likely to be true as the intercept appears to be constant over very wide ranges of frequency.

From Figs. 4, 5 and 6 the loss of a condenser at any given frequency F can be put in the form of an equivalent series resistance R given by

$$R = a + \frac{1}{b'C^2} \quad \cdots \quad \cdots \quad (1)$$

where a and b' are constants. a is independent of frequency over a very large range, while b' is a function of the frequency.

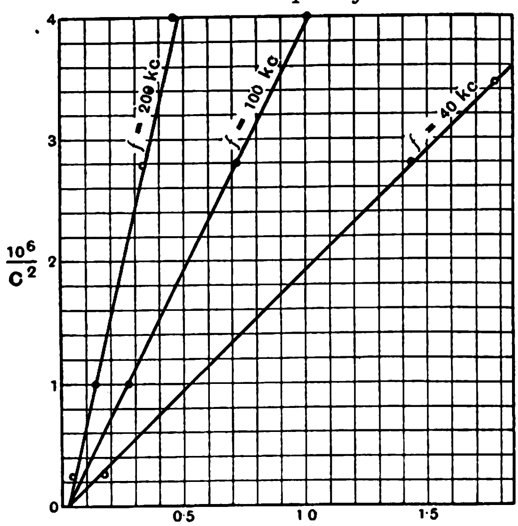


Fig. 5.

The next step was to find the variation of b' with frequency. A remarkable result was here obtained.

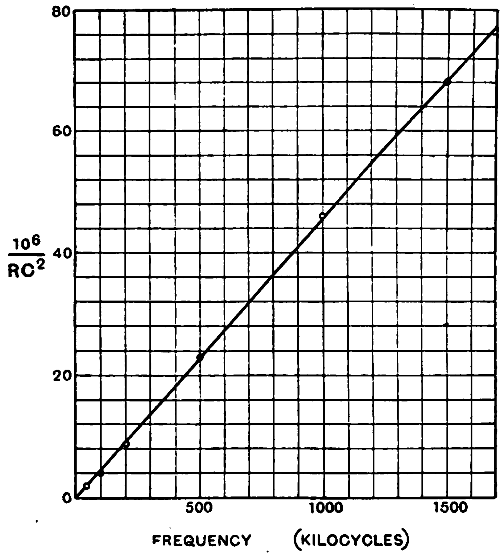


Fig. 6.

If the gradient of the curves such as those given in Figs. 4 and 5 be plotted against the frequency, as is done in Fig. 6, an accurate straight line passing through the origin is obtained. The final empirical law is, therefore,

$$R = a + \frac{1}{bC^2 f} \quad \cdots \quad \cdots \quad (2)$$

where a and b are constants.

The power factor P of the condenser is, therefore, given by

$$P = aC\omega + \frac{2\pi}{bC} \quad \cdots \quad \cdots \quad (3)$$

The results shown in Figs. 3, 4 and 5 give

$$a = 0.02$$

and $$b = 46 \times 10^{-6}$$

where C is in micro-microfarads.

The results given in Fig. 7 are interesting, for they represent a condenser in which the series resistance a was large. The first results gave curve (b). On tightening the bolts screwing the plates together, this line was altered to the line (a). The lines are accurately parallel so that the dielectric losses have remained unaltered, but the resistance was materially reduced.

The above empirical law (equation 2) has been tested for air condensers having as insulating material amber, keramot,* quartz and ebonites variously loaded and having been variously exposed to sunlight.

The Use of a Guard Ring.

When measuring the power factor of dielectrics, it is necessary, in order to obtain very accurate results, that a guard ring should be used. The method previously described by the author for the use of a guard ring in the ordinary variation of resistance method (" Note on the Measurement of Dielectric Losses and Permitivity at Radio Frequencies," *E.W. & W.E.*, Vol. 4,

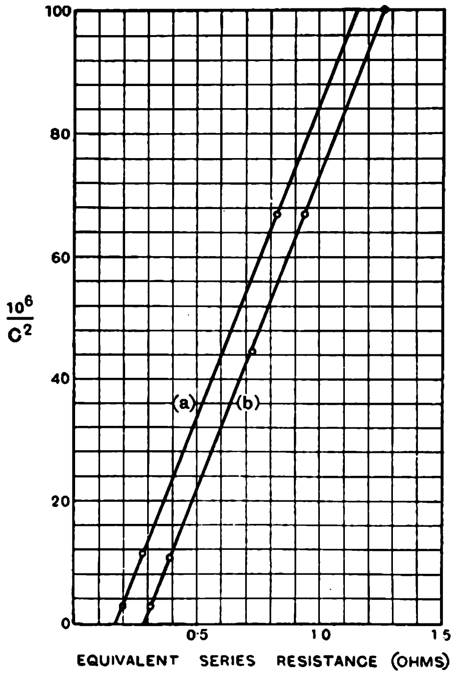


Fig. 7.

1927, pp. 569–570) can be applied to the substitution method described above.

In this case the coil L (Fig. 2) should be made of stranded wire, one strand of which is connected to special terminals on the switch Q, Fig. 8. This strand, whatever the position of the switch Q, has one or other

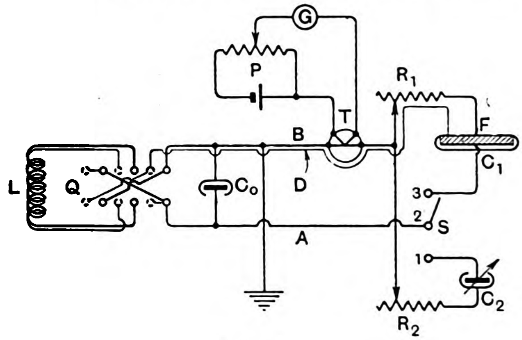


Fig. 8.

of its ends connected to the wire A and the other to a wire D closely intertwined with the wire B. The wire D follows closely the circuit containing the dielectric C_1 under measurement and is connected to the guard ring. The guard ring is shown completely screening the central electrode except for a portion F, which is connected to the resistance R_1 as in an ordinary measurement.

It will be seen that the potentials of the guard ring and of the plate F are practically identical, apart from the small ohmic drops and whatever small E.M.F. may be induced between the two closely intertwined circuits, but that the dielectric current flowing to the guard ring passes neither through the resistance R_1 nor the thermo-ammeter T. Apart from a small correction which may be applied for the air-gap between the plate F and the guard ring, the electric lines of force between the plate F and the central electrode should be very nearly straight and parallel.

The author has had no occasion to use a guard ring and has not tried the method experimentally, but he feels confident that it should prove satisfactory. Should any reader try it the author would be very glad to hear what difficulties are encountered and what success is obtained.

* A loaded red ebonite.

On the Effect of the Ground on Downcoming Plane Space-Waves.

By E. T. Glas.

THE state of polarisation of radio waves has in recent years been the subject of much investigation, experimental, as well as theoretical. As a matter of fact, however, the results which can be unreservedly accepted are not abundant, particularly from the theoretical point of view. As successful workers we find especially T. L. Eckersley, Smith-Rose and Barfield in England, and Pickard and Alexanderson in the United States. A preliminary theory of the variable state of polarisation due to the influence of the earth's magnetic field was given in the year 1925 by Nichols and Schelleng,* of the United States. According to their theory the rotation of the plane of polarisation (we define this plane as is usual among radio engineers as the plane containing the electric vector and the direction of propagation) tends towards a certain limit, independent of wavelength, for extremely long space-waves, whilst it grows smaller and smaller for very short waves as the wavelength decreases. The original magneto-optical theory has been shown by P. O. Pedersen,† of Denmark, to contain several errors. The main cause of these errors is that the frequency of collision between the charged particles has not been taken into account from the start. Thus the correct attenuation does not appear in the formulas of Nichols and Schelleng. Pedersen has worked out the theory more completely and has shown that the rotation of the plane of polarisation also decreases continuously for the extremely long waves without reaching any constant limit. The phenomenon should not consequently be marked on extreme wavelengths. The main cause of the highly variable state of polarisation on short waves ($\lambda < 100$ m.) is attributed to asymmetrical structure of the conducting layer by v. Korshenewsky.‡ Some portions, like clouds of this layer, will deviate the electric vector from the original angle with the vertical line, thus causing rotation of the vector. If this explanation is correct, all kinds of polarisation ought to be equally probable. A certain polarisation, such as a horizontal one, does not follow, but Pickard§ proved in the year 1926 that horizontal polarisation may dominate on the usual short waves. It is doubtful, however, if the influence of the ground was actually eliminated by the fact that the measurements were undertaken in a raised wooden tower 7 metres in height. Pickard's conclusions can be summarised as follows: the state of polarisation depends on wavelength, distance and time of day, but not on the type of transmitting aerial or geographical position of transmitter. No selective effect with regard to the magnetic meridian could thus be traced. Meissner,|| also, in Germany, did not succeed in finding any such effect, transmitting in the vicinity of the "critical frequency" ($\sim$200 m.) in different directions during night-time. The magneto-optical theory in its present state cannot at all explain the rotation into a vertical direction of a field that is horizontally polarised near the transmitter as observed by Alexanderson¶ of the United States, because such a rotation is only predicted by the present theory for the component of the electric vector propagated along the earth's magnetic lines; it decreases very rapidly with decreasing wavelength, and in no case tends to attain a definite limit. Appleton,** Hollingworth and Naismith††, in England, among others, have found circular or approximately circular polarisation both on the long commercial waves and the lower broadcasting-band.

* *The Bell System Technical Journal*, April, 1925.

† P. O. Pedersen: "The Propagation of Radio Waves," Copenhagen, 1927, Chapter VII.

‡ Jahrbuch der D.T., Dec., 1926.

§ *Proc. Inst. Rad. Eng.*, April, 1926.

|| *Elektrische Nachrichtentechnik*, Sept., 1926.

¶ *Ingeniörsvetenskapsakadeniens Handlingar, No.* 48: "Radio Wave Propagation," by E. F. W. Alexanderson, Stockholm. 1926.

** *E.W. & W.E.*, May, 1928.

†† *Nature*, 4 Febr., 1928, etc.

This phenomenon can possibly be attributed to magneto-optical dispersion, but the matter is not yet proved.

It is rather tempting to assume that the phenomena dealt with can be attributed, at least partly, to the influence of the conducting surface of the earth, more particularly as the published experimental investigation seems to be restricted to the proximity of this surface. Of course, it is the resultant

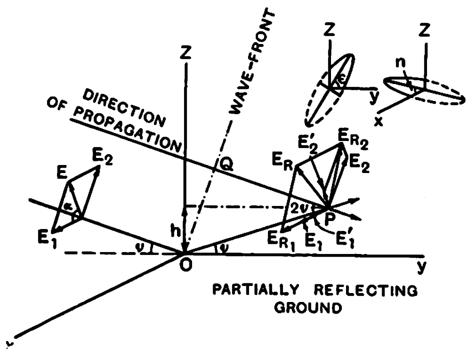


Fig. 1.—*Distortion of wave-front by reflection at a conducting surface. Above are shown the elliptical loci indicating apparent direction of electric field as well as state of polarisation.*

field, the components of which are formed by the direct downcoming radiation and the indirect radiation due to the ground by reflection or otherwise, that is measured. This resultant and the originally downcoming field may possess different properties. Consequently the pure space-radiation may be but little accessible to measurements at the earth's surface. In the following calculations we consider a homogeneous downcoming radiation forming the angle δ with the surface of the earth. Thus all the rays are equal and parallel to each other. We assume the electric field to be originally a pure alternating one. The influence of the ground will be referred to by introducing the reflected rays. The refracted ones, which penetrate into the earth, are wasted. Nevertheless, the corresponding earth-currents give rise to a field above the surface. This field will however not be taken into consideration beside the reflected field. Starting from these assumptions it is proposed to show how the originally pure field will be distorted by superposition of the reflected field. In fact, an elliptical, rotating field will result. When the field-ellipses are sufficiently narrow we can, to a first approximation, content ourselves by studying the direction and size of the major axis.

Let $E = E_0 \, . \, e^{j\omega t}$ be the electric field-vector of the downcoming radiation, the polarisation of which is determined by the angle α in Fig. 1. Further, let E_R be the field-resultant after the aforementioned superposition. Inspection of Fig. 1 will verify the following equations.

1.—*Field-component perpendicular to the plane of incidence* E_{R_1} (in the xz-plane)

$$\left.\begin{aligned} E_z &= (E_2 + E_2') \, . \cos\delta \\ E_x &= E_1 + E_1' \end{aligned}\right\}$$

At the origin O we have

$$E_1' = E_0 \, . \cos\alpha \, . f_1 \, . \, e^{j\theta_1}$$

where f_1 is the coefficient of reflection perpendicular to the plane of incidence and Θ_1 the corresponding additive phase-angle. At the height h above the surface of the earth we have to add a phase-angle, which is due to the difference of path $OP - QP$ or $2h \sin\delta$. Thus

$$\left.\begin{aligned} &E_2 + E_2' = E_0 \, . \sin\alpha \, . \\ &\quad\left\{\cos\omega t + f_2 \, . \cos\left(\omega t + \Theta_2 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta\right)\right\} \\ &E_1 + E_1' = E_0 \, . \cos\alpha \, . \\ &\quad\left\{\cos\omega t + f_1 \, . \cos\left(\omega t + \Theta_1 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta\right)\right\} \end{aligned}\right\}$$

Substituting

$$\Theta_1 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta = \psi$$

$$\Theta_2 + 4\pi \, . \frac{h}{\lambda} \, . \sin\delta = \phi$$

we further have

$$\left.\begin{aligned} &\cos\omega t \, . \, (1 + f_1 \, . \cos\psi) \\ &\qquad - \sin\omega t \, . f_1 \, . \sin\psi = x \, . \frac{1}{\cos\alpha} \\ &\cos\omega t \, . \, (1 + f_2 \, . \cos\phi) \\ &\qquad - \sin\omega t \, . f_2 \, . \sin\phi = z \, . \frac{1}{\sin\alpha \, . \cos\delta} \end{aligned}\right\}$$

where
$$x = \frac{E_x}{E_0}$$

$$z = \frac{E_x}{E_0}$$

Finally eliminating the time (t) we have the equation

$$A_1 \, . \, x^2 - 2 \, . \, B_1 \, . \, xz + C_1 \, . \, z^2 = D_1 \, . \, . \quad (1a)$$

with the coefficients

$$\begin{cases} A_1 = 1 + f_2^2 + 2f_2 \, . \cos \phi \, ; \\ B_1 = \dfrac{\cot \alpha}{\cos \delta} \, . \, [1 + f_1 \, . \cos \psi \\ \qquad + f_2 \, . \cos \phi + f_1 f_2 \, . \cos (\phi - \psi)] \, ; \\ C_1 = \left(\dfrac{\cot \alpha}{\cos \delta}\right)^2 . \, (1 + f_1^2 + 2f_1 \, . \cos \psi) \, ; \\ D_1 = \cos^2 \alpha \, . \, [f_1 \, . \sin \psi \\ \qquad - f_2 \, . \sin \phi - f_1 f_2 \, . \sin (\phi - \psi)]^2 \, ; \end{cases}$$

Evidently the locus (1a) is an *ellipse*, whose equation by well-known analysis can be reduced to a simple form. To do this, turn the axes counter-clockwise an angle η satisfying

$$\tan 2\eta = 2 \, . \frac{\cot \alpha}{\cos \delta} \frac{1 + f_1 \, . \cos \psi + f_2 \, . \cos \phi + f_1 f_2 \, . \cos (\phi - \psi)}{\left(\dfrac{\cot \alpha}{\cos \delta}\right)^2 . \, (1 + f_1^2 + 2 f_1 \, . \cos \psi) - (1 + f_2^2 + 2f_2 \, . \cos \phi)} \quad .. \quad .. \quad (1b)$$

To find the relative position of the axes we calculate the ratio of the intercepts on the x and z axes

$$k_1 = \sqrt{\frac{c_1}{a_1}}$$

Finally the axes are calculated from

$$a = \sqrt{\frac{D_1}{A_1'}} \qquad b = \sqrt{\frac{D_1}{C_1'}} \quad .. \quad (1c)$$

where A_1', C_1' are the two roots of the following equation

$$u^2 - (A_1 + C_1) \, . \, u = B_1^2 - A_1 C_1$$

The state of polarisation, originally plane and rectilinear, is thus changed to elliptical. In fact, the point of the component-vector perpendicular to the plane of incidence moves along an elliptical path determined by the formulæ 1a, 1b, 1c.

2.—*Field-component in the plane of incidence* E_{B_2} (in the yz-plane).

$$\left.\begin{aligned} E_z &= (E_2 + E_2') \, . \cos \delta \\ E_y &= (E_2 - E_2') \, . \sin \delta \end{aligned}\right\}$$

At the origin O after reflection in the plane of incidence we assume

$$E_2' = E_0 \, . \sin \alpha \, . f_2 \, c^{j\theta_2}$$

where f_2 is the coefficient of reflection in the plane of incidence and Θ_2 the corresponding phase-angle. Introducing

$$y = \frac{E_y}{E_0} \text{ and } z = \frac{E_z}{E_0}$$

calculation analogous to that in the preceding section, will give a locus of the form

$$A_2 \, . \, y^2 - 2 \, . \, B_2 \, . \, yz + C_2 \, . \, z^2 = D_2 \quad .. \quad (2a)$$

where

$$\left.\begin{aligned} A_2 &= 1 + f_2^2 + 2f_2 \, . \cos \phi \\ B_2 &= (1 - f_2^2) \, . \tan \delta \\ C_2 &= (1 + f_2^2 - 2f_2 \, . \cos \phi) \, . \tan^2 \delta \\ D_2 &= (2 \, . \sin \alpha \, . \sin \delta \, . f_2 \, . \sin \phi)^2 \end{aligned}\right\}$$

Again we get an *ellipse* (2a). Now turn the axes counter-clockwise an angle ϵ so that

$$\tan 2\epsilon = - \frac{\sin 2\delta \, . \, (1 - f_2^2)}{(1 + f_2^2) \, . \cos 2\delta + 2 \, . f_2 \, . \cos \phi} \quad .. \quad .. \quad (2b)$$

The ratio of the intercepts on the y- and z-axes is

$$k_2 = \sqrt{\frac{C_2}{A_2}}$$

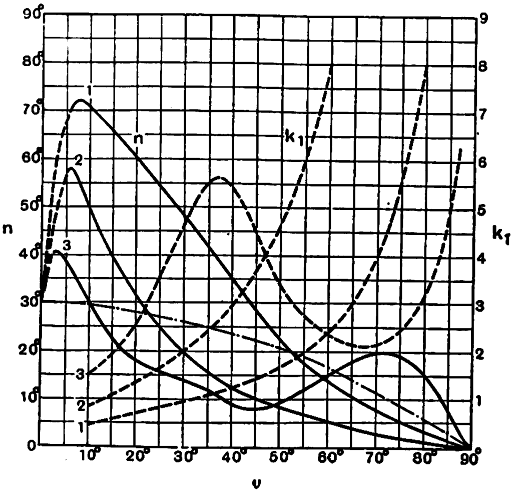


Fig. 2.—*Field ellipse perpendicular to the plane of incidence* ($\alpha = 30°$), $\lambda = 26.5$ *m. Inclination of major axis to ground and ratio of intercepts.* —·—·— *no reflection from the ground.* 1 $\frac{h}{\lambda} = \frac{1}{8}$: 2 = $\frac{1}{4}$: 3 = $\frac{1}{2}$.

The axes themselves can be found from

$$a = \sqrt{\frac{D_2}{A_2'}} \qquad b = \sqrt{\frac{D_2}{C_2'}} \quad .. \quad (2c)$$

A_2', C_2' being roots of

$$u^2 - (A_2 + C_2) \, . \, u = B_2^2 - A_2 C_2$$

A measurement of the apparent earth-angle of downcoming space-waves may thus not give any sharp value as the field in the plane of incidence is not pure but elliptical. Also, the true earth-angle is not necessarily obtained unless the influence of ground can be safely eliminated.

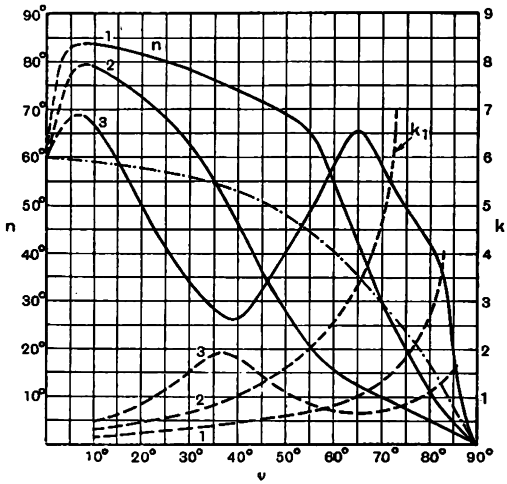


Fig. 3.—*Field ellipse perpendicular to the plane of incidence.* ($\alpha = 60°$), $\lambda = 26.5$ *m. Inclination of major axis to ground and ratio of intercepts.* —·—·— *no reflection from the ground.* $1\frac{h}{\lambda} = \frac{1}{8}$: $2 = \frac{1}{4}$: $3 = \frac{1}{2}$.

As the derived formulæ are complicated a numerical calculation would be rather laborious. We reproduce graphically the actual result for a short wavelength ($\lambda = 26.5$ m.) assuming the conductivity of the earth to be $H = 5.10^{-14}$ e.m.u. The state of polarisation of the downcoming plane waves may be given by $\alpha = 30°$ or $\alpha = 60°$. The earth-angle of the major axes of the field-ellipses (η, ϵ), and the ratio of the intercepts on the x-, y- and z- axes (k_1, k_2) are calculated for the plane of incidence and for a plane perpendicular to it as functions of the earth-angle of the downcoming radiation. Three different heights above ground are considered namely,

$$h = \tfrac{1}{8}\lambda,\ \tfrac{1}{4}\lambda,\ \tfrac{1}{2}\lambda$$

The corresponding curves are shown in Figs. 2, 3, 4.

The curves in Pedersen's* above-mentioned work, showing f_1, f_2 as well as θ_1, θ_2 for different wavelengths, earth-angles and conductivity of ground have been used in order to simplify the calculation.

Some field-ellipses are worked out in Figs. 5, 6, and 7 for $\delta = 20°$, but for various heights above ground and different original polarisation.

The following conclusions may be drawn from this numerical example.

(1) A relatively steep radiation (large value of δ) may give narrow ellipses and consequently a pure field. Nevertheless, a nearly grazing incidence will give the same result (very small δ).

(2) The field-component in the plane of incidence is rather pure but somewhat raised or tilted owing to the influence of ground. Thus the apparent direction of propagation differs from the true one.

(3) The state of polarisation of the downcoming radiation is altered. A steep radiation may be more horizontally polarised, but a radiation the rays of which form a relatively small angle with the surface of the earth will to a certain limit always be more vertically polarised.

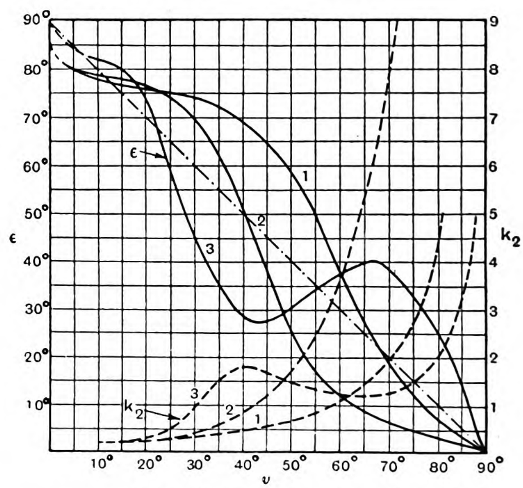


Fig. 4.—*Field ellipse in the plane of incidence.* $\lambda = 26.5$ *m. Inclination of major axis to ground and ratio of intercepts.* —·—·— *no reflection from the ground.* $1\frac{h}{\lambda} = \frac{1}{8}$: $2 = \frac{1}{4}$: $3 = \frac{1}{2}$.

(4) The resulting field which is generally elliptically polarised is very dependent on the height above ground as regards its intensity, purity and polarisation.

* Loc. cit., pp. 132–135. Owing to different definitions from the start, Pedersen's value of θ_2 differs from our value by π.

Long-distance communication on short waves is probably due either to rays emitted with small earth-angle or to rays which penetrate directly from the transmitter to a considerable height, where the radius of curvature of the path equals the radius of

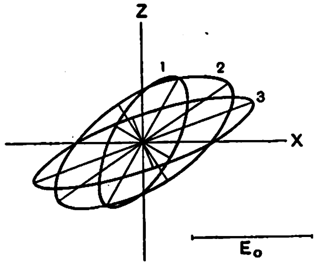


Fig. 5.—*Field ellipses perpendicular to the plane of incidence.* $a = 30°$, $\delta = 20°$, $\lambda = 26.5$ *m.* $1\frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$.

the earth. With regard to the first alternative the really grazing rays as a rule should not be of considerable importance, because the topographical conditions and the highly variable state of the lower atmosphere disturb the propagation. The second manner of propagation—the rays, so to speak, sliding forwards at constant height above the surface of the earth and reaching this surface by gradual leakage far from the transmitter —is strongly emphasised by Pedersen.* This author shows how improbable the propagation by multiple-reflection from the earth's surface ought to be if the serious

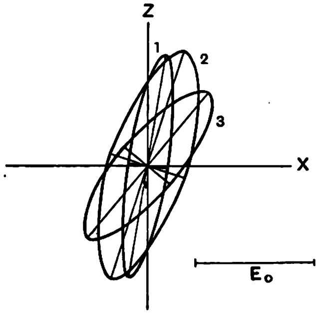


Fig. 6.—*Field ellipses perpendicular to the plane of incidence.* $a = 60°$, $\delta = 20°$, $\lambda = 26.5$ *m.* $1\frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$.

loss by such a reflection on very short waves is considered. Pedersen's view seems to be consistent with the experimental results of Friis† in the United States. Friis measured, among other quantities, the earth-angle of downcoming radiation from the well-known beam-transmiitter at Bodmin (GBK 16 m.). He found that the earth-angle was continually varying within wide limits up to $\delta = 60°$. It is difficult to explain the existence of such a steep ray at $\lambda = 16$ m. in any other way, remembering the small refractive power of the ionised layer on this typical daylight-wave and assuming the earth-angles to be substantially equal at the transmitter and the receiver. The existence of relatively steep rays ($\delta = 30° - 60°$) at great distance makes it probable

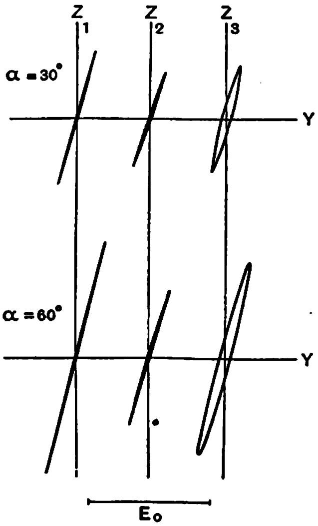


Fig. 7.—*Field ellipses in the plane of incidence.* $\delta = 20°$, $\lambda = 26.5$ *m.* $1\frac{h}{\lambda} = \frac{1}{8} : 2 = \frac{1}{4} : 3 = \frac{1}{2}$

that horizontal and non-linear (*i.e.*, circularly polarised) resulting fields may be created by the action of ground-reflection independent of distance or magneto-optical influence (Figs. 2 and 3).

We can probably look for systematical errors in the measurements of the earth-angle of a downcoming ray where the influence of ground is not eliminated, because the resulting field, whether pure or not, only gives an apparent value.

The continually changing polarisation of the resultant field by ground-reflection with

* Loc. cit., p. 199.

† *Proc. Inst. Rad. Eng.*, May, 1928.

varying earth-angle may possibly explain the variation of the rotation of the plane of polarisation as the distance from the transmitter increases, discovered by Alexanderson*. By inspection of Figs. 2 and 3 we find that the polarisation in the case considered tends to be more vertical as the earth-angle decreases, the really grazing incidence not included. Further from the transmitter the earth-angle as a rule decreases, as the rays emitted relatively near the surface of the earth seem to be most important for some experienced long-distance communication†, and certainly should be so for "moderate long-distance" propagation. Consequently, *the polarisation may become more vertical with increasing distance due to the influence of the ground itself*, as observation indicates.

The field-structure thus varying with the height above ground, the total induction in a receiving aerial should be extremely complicated. Equalising currents are likely to be caused, the resulting action of which is not easy to predict. As a matter of fact, the most suitable form of a receiving aerial for short waves cannot be designed in advance. Very peculiar shapes of aerials, as is well known, may give good reception.

The foregoing discussion of the deforming action of the ground on downcoming space-radiation has been numerically restricted to a special case which, for the purpose of the problem, has been considered as typical. The object has been to raise the question whether the ground itself cannot be held responsible for some peculiar phenomena observed in short-wave work.

* Loc. cit., p. 4.

† *Journal I.E.E.*, T. L. Eckersley "Short Wave Wireless Telegraphy," extr., *E.W. & W.E.*, April, 1927, p. 220.

Book Review.

SPEECH AND HEARING. By H. Fletcher. (Macmillan and Co., Ltd., 1929. 20s.)

This is an invaluable account of recent work on the attributes of speech and hearing which can be physically measured, with special reference to the investigations carried out by the Bell Telephone Laboratories during the last fifteen years. The preliminary work of analysing electrical currents into their component frequencies and of measuring the intensity of such frequencies is first described, together with the devices for examining the performance of telephones and loud-speakers.

Next we are given an analysis of the mechanism of speaking, the artificial production of speech sounds, and figures as to speech power in various circumstances.

Wherever possible, figures are expressed in decibels, which have replaced the old transmission units; thus we are told that if average speech power be taken as unity, very loud speech is 20 decibels up, weak speech is 20 decibels down, and a soft whisper is 40 decibels down.

Part 2 gives the acoustic spectra of typical musical instruments: at low frequencies the piano gives harmonics strongly, but the fundamental is almost silent: with the clarinet the high harmonics are powerful and the tenth harmonic has one-half the amplitude of the fundamental. Various methods have been devised for measuring noise, and noise surveys are given for streets and busy offices; in an average typist's office the noise is such that speech must be raised by 30 decibels to override the noise: in the noisiest street in New York the figure is 50 decibels, i.e., speech must be made 100,000 times as loud as in quiet surroundings.

Part 3 opens with the examination of the sensitivity of the ear to change of pitch and intensity: we can detect about 2,000 gradations of pitch in the audible region. A fascinating chapter deals with the masking of one tone by another. A low pitched tone deafens the ear for tones in the immediate pitch region, but if the disturbing tone is made more intense harmonics are generated in the ear which obliterate sound of more distant pitch and a very loud tone of low pitch obliterates all other sounds.

In Part 4 we are told the amount of distortion which speech can suffer before the intelligibility becomes gravely affected. A strange result is that although 60 per cent. of the energy of speech is carried by frequencies below 500 c.p.s., yet the suppression of these frequencies only decreases the intelligibility by 3 per cent.

The book shows that the problems of speech, hearing, and noise can now be treated quantitatively: accordingly, we can approach two great problems in a systematic way: one is the menace of noise; the other is the making of feminine speech intelligible over the telephone.

R.T.B.

Book Received.

TELEGRAPHY AND TELEPHONY, INCLUDING WIRELESS. By E. Mallett, D.Sc.(Eng.), London.

An introductory text book to the science and art of the electrical communication of intelligence. Comprising Line Telegraphy for short and long lines; Line Telephony including a chapter on manual and automatic exchanges; Wireless Telegraphy and Telephony and an appendix of mathematical formulæ and tables relating to the subjects dealt with. Pp. 413 + ix with 287 diagrams and illustrations. Published by Chapman & Hall, Ltd., price 21/- net.

A Sensitive Valve Voltmeter Without "Backing Off."

By Manfred Von Ardenne.

FOR the measurement of alternating voltages *greater* than one volt, there is available a whole series of quite simple arrangements suitable for practical needs. For measurements of amplification, however, where the voltages used cannot overstep certain limits without introducing overloading, it is required to determine accurately voltages of *less* than one volt. Even voltages of this order can be determined with the aid of a valve voltmeter. The peculiarity by which such sensitive valve voltmeters can be recognised is usually the compensation of the anode current, or "backing off."* By compensation of the current in the anode circuit of the voltmeter the range of measurement is considerably extended in the direction of small voltages, since a more sensitive instrument can be substituted for the milliammeter usually employed. But the introduction of compensation increases the difficulties of using and reading the voltmeter, and there is always the danger that the measuring instrument mentioned may be damaged by too great a voltage. For these reasons it is desirable to avoid "backing off," and to attain high sensitivity by other means.

The Construction and the Properties of a Sensitive Valve Voltmeter.

The circuit† of a valve voltmeter that is very sensitive, but yet does not employ the principle of "backing off," is shown in Fig. 1. The rectification of the voltage to be measured is achieved in a stage consisting of a valve of high amplification factor in the anode circuit of which there is a resistance of several million ohms, bridged, for the frequency of the alternating current to be measured, by a condenser. With the values of components given the necessary bridging capacity across the anode resistance is satisfactory for all frequencies over about 50 cycles, so that the calibration of the voltmeter is independent of frequency for all higher values of the latter, no matter

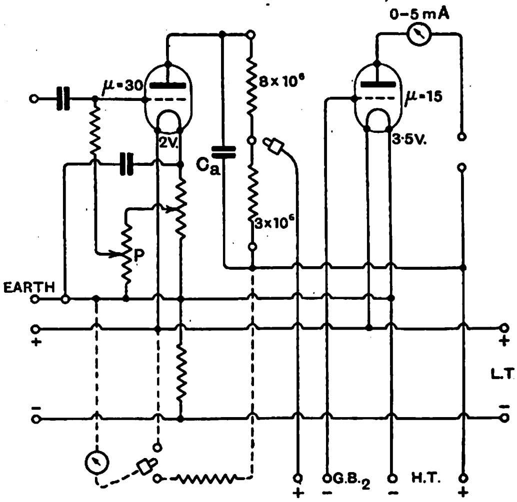


Fig. 1.

whether audio- or radio-frequencies are being dealt with. It is therefore possible in practice to calibrate the voltmeter with a medium audio-frequency, and to use it with this same calibration at high frequencies. This type of anode rectification, which has already been proposed for the construction of sensitive voltmeters‡, is, as measurements have shown, more sensitive than normal anode rectification in which there is no anode resistance§, and is very nearly as sensitive as leaky-grid rectification.

* In this connection attention should be drawn to the important paper "The Thermionic Voltmeter," by W. B. Medlam and U. A. Oschwald, EXPERIMENTAL WIRELESS, 1926, No. 37 and following issues.

† M. von Ardenne, "Ein empfindliches Röhrenvoltmeter für Hochfrequenz," *E.T.Z.*, 1928, Part 15.

‡ "Ueber Anodengleichrichtung," *Zeitschr. für Hochfrequenztechnik*, Vol. 28, p. 87.

§ "Ueber Anodengleichrichtung II," *ibid*, Vol. 31, p. 51.

The special advantage of this type of anode rectification for the purpose of measurement lies in its relatively great independence of the battery voltages applied. In contrast to leaky-grid detection, and ordinary anode-bend detection, with which it is always necessary to work at a point of maximum curvature of the grid-current or anode current curve, in the present type of rectification the presence of the high anode resistance ensures an *automatic* adjustment to a point of great curvature of the anode-current curve. In Fig. 2 is given the characteristic of a stage used for rectification, together with the measured response to alternating voltages of frequency 800 cycles for various values of the condenser in the anode circuit. It will be seen from these curves that the response of the rectifier when using the battery voltages mentioned, and which are those intended for use in the completed voltmeter, is only subject to very small percentage variations over a range of grid potential of nearly 3 volts. When carrying out measurements with such an instrument, the constancy of calibration produced by this peculiarity of the rectifying stage is extremely convenient. It will later be shown in more detail that in this type of circuit the calibration is not only comparatively independent of the control-voltages, but is also nearly independent of the filament voltage. From the fact that in a circuit of this kind, the valve is operated with voltages much smaller than those for which it was originally designed, it is found possible to employ valves with thoriated cathodes without incurring appreciable variations in the emission.

Fig. 1 shows that the rectification effect is not measured directly in the first stage, but that the change in anode voltage produced here is measured in the plate circuit of a second valve coupled, through a battery, to the first. This second valve, especially if it has a high mutual conductance, enhances very considerably the sensitivity of the voltmeter, as is well known from other circuits. In order to prevent the second stage from interfering with the adjustments of the first, care must be taken that the grid current of the second valve is always small in comparison with the very low anode current of the first. For this reason it is necessary to use in the second stage a valve with a good vacuum, and to provide a suitable grid-battery $G.B._2$ for supplying a large enough grid bias. The voltage of this battery must be a little greater than the anode voltage which appears on the recti-

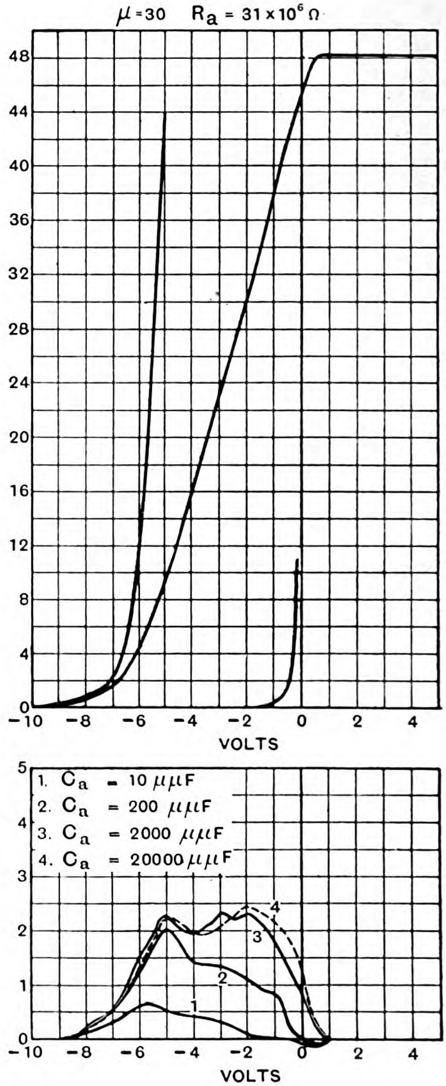


Fig. 2.

fying valve when adjusted to its working point.

In order to make it possible to measure voltages lying within various ranges, the anode resistance of the first stage is divided into sections. As with every change of con-

nection here the direct-voltage conditions with respect to the second valve change, it is necessary to make a corresponding change in the voltage tapped off from the second grid-battery whenever a change is made from one range to another.

The potentiometer P in Fig. 1, in parallel with a small part of the filament resistance, is used to adjust the working point of the first valve to such a point on the characteristic that by the use of a high enough voltage from the battery $G.B._2$ the instrument situated in the anode circuit of the second valve shows exactly full-scale deflection. For modern valves ($\mu = 15$) the range of this instrument will be chosen so that it reads up to about 5 milliamps. As the response of such an instrument is very rapid, high-frequency measurements with this valve voltmeter occupy no more time than simple measurements of direct current.

If alternating voltages are applied to the voltmeter, the current in the anode circuit of the rectifying stage increases, and as a result the anode current of the second stage falls to a more or less small value. The calibration curves of a voltmeter built to the circuit, and with the values of components shown in Fig. 1, are reproduced in Fig. 3 to give an idea of the results obtainable. On this diagram are also given the values of the working voltages and for the voltage of the grid-battery for two different ranges. With a milliammeter that permits the detection of a current variation of a fiftieth of a milliampere it is possible to measure alternating potentials of 0.01 volt. Thus in practice about the same sensitivity is attained as with valve voltmeters in which compensation of the anode current is employed.

In contrast to these instruments, it is claimed as a special advantage of a voltmeter on the lines indicated in Fig. 1 that if a large alternating voltage is applied the deflection of the measuring instrument in the anode circuit of the second valve drops down to zero, so that in spite of the high sensitivity overloading of this instrument is practically impossible.

There is shown in Fig. 1 a grid-leak and condenser on the input side of the voltmeter, in order to make it possible to measure an alternating voltage upon which is superposed a direct voltage. If only alternating voltages are to be measured, this combination can, of course, be omitted, and the alternating voltage can be connected directly between grid and the potentiometer P. In this case no damping of the circuit being measured by the grid-leak occur.

At high frequency an appreciable load can also be caused by the grid capacity of the voltmeter; this is chiefly due to the static capacities between grid-and-anode and grid-and-cathode of the first valve. To attain the smallest possible loading of

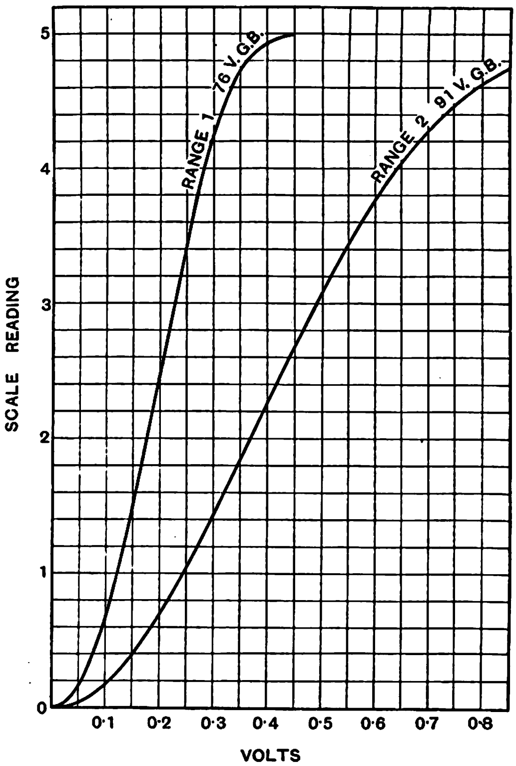


Fig. 3.—*Calibration curves of the valve voltmeter.*

the input circuit at high frequencies, the grid capacity must be reduced as far as possible. In a valve voltmeter on the lines of Fig. 1, the interior of which is shown in Fig. 4, a capacity of only 6 $\mu\mu$F was found between the grid-terminal and earth. To this capacity must be added that between the connecting wires to the terminals of the voltmeter and earth, which, with wires of about 20 to 30 cms. length, amounts to about 3 $\mu\mu$F. The total capacity of a valve voltmeter such as that of Fig. 1 need not

therefore exceed 9 $\mu\mu$F. This value of capacity is small enough to permit of carrying out exact measurements of amplification, even on wavelengths down to 200 metres.

In order to keep the grid-capacity as small as possible, the grid-lead was arranged to be as far as possible from all other wires. In the interest of low capacity the valve used as rectifier was de-capped. In this connection it is worth mentioning that in the rectifying stage a *screened-grid valve* with separate lead for the grid, such as has been developed in America for use with aperiodic frame aerials, has great advantages.

The outside of the instrument of which Fig. 4 shows the interior, may be seen in Fig. 5. The voltage to be measured is led to the instrument by the shortest route through the hole visible on the left-hand side of the containing box. For practical work with the instrument described, there is a certain convenience in the fact that the adjustment of the operating point for the second stage, and above all the sensitivity, are within certain limits practically independent of the filament voltage. There is, therefore, no need to take any elaborate precautions to ensure that the filament voltage is adjusted to exactly the value at which the calibration curves were made.

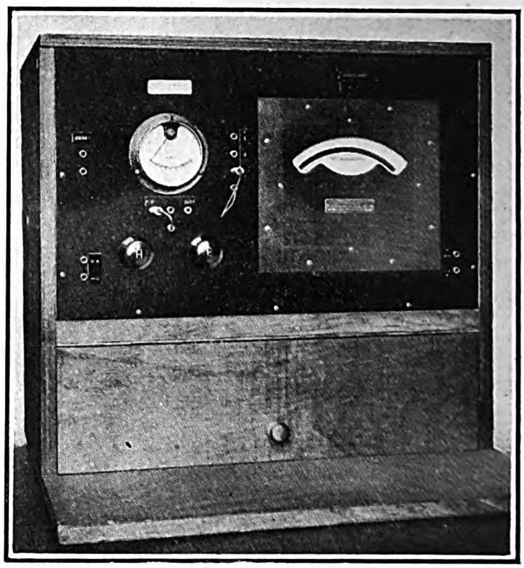


Fig. 5.—*External view.*

In a circuit of this type an increase of the filament voltage in the first stage only results in a certain decrease in the anode current in the second stage. On the other hand, if the filament voltage is increased in the second stage only, the plate current increases. It must be ascribed to a lucky

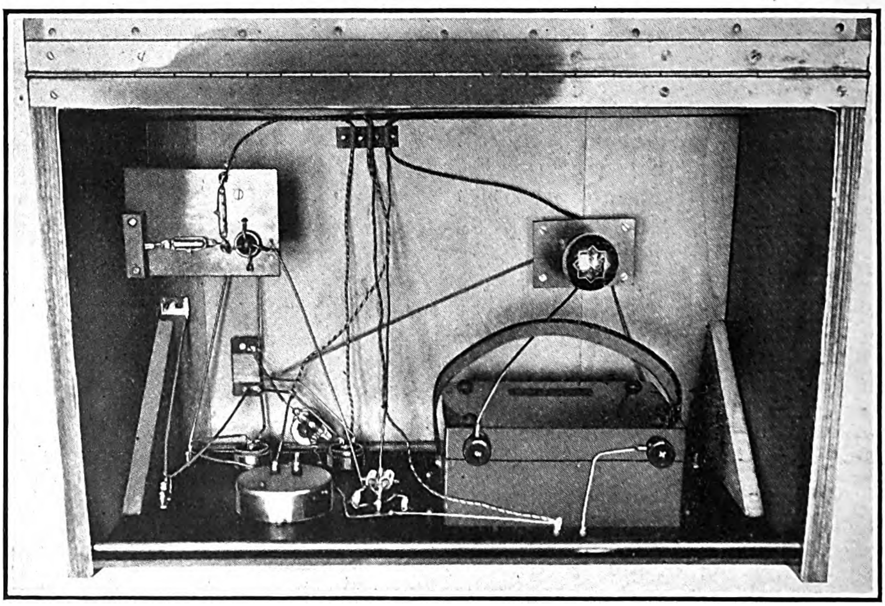


Fig. 4.—*Interior of the voltmeter.*

accident that variations in filament voltage occurring in both stages simultaneously almost exactly counterbalance one another, so long as the variations are small.

The special advantages of the valve voltmeter described are now briefly summarized as follows :—

High sensitivity is obtained without the use of current-compensation; in consequence the time spent in adjusting the instrument is small.

Damage by overloading is almost impossible.

The calibration-curve is independent of frequency for all frequencies above 50 cycles, so that measurements may be undertaken at both high and low frequency. Within certain limits the variation with battery-voltage is small, so that the anxious care that has to be bestowed on obtaining perfect constancy of voltage for most other types of valve voltmeter is here not nearly so essential.

The stray capacities amount to only a few micromicrofarads, and are small enough to permit the carrying-out of nearly all high-frequency measurements.

The Use of the Valve Voltmeter.

Measuring arrangements, in which a valve voltmeter is used in conjunction with an audio-oscillator and a resistive potential-divider for determining the degree of amplification of a low-frequency amplifier at different audio-frequencies have already been described so often that it would be superfluous to go into the details of such an arrangement here. The valve voltmeter is specially suited* for measurements on high-frequency amplifiers, which have been regarded up to the present as being the most difficult measurements to make in the whole range of receiver technique. With an equipment such as that shown in Fig. 6, these measurements are however so simplified that it is possible to determine, for example, the amplification attained on any given wavelength by the use of a multiple valve within the space of a few seconds. The measuring equipment consists of a high-frequency generator, a calibrated resistive potential divider for high frequencies, and

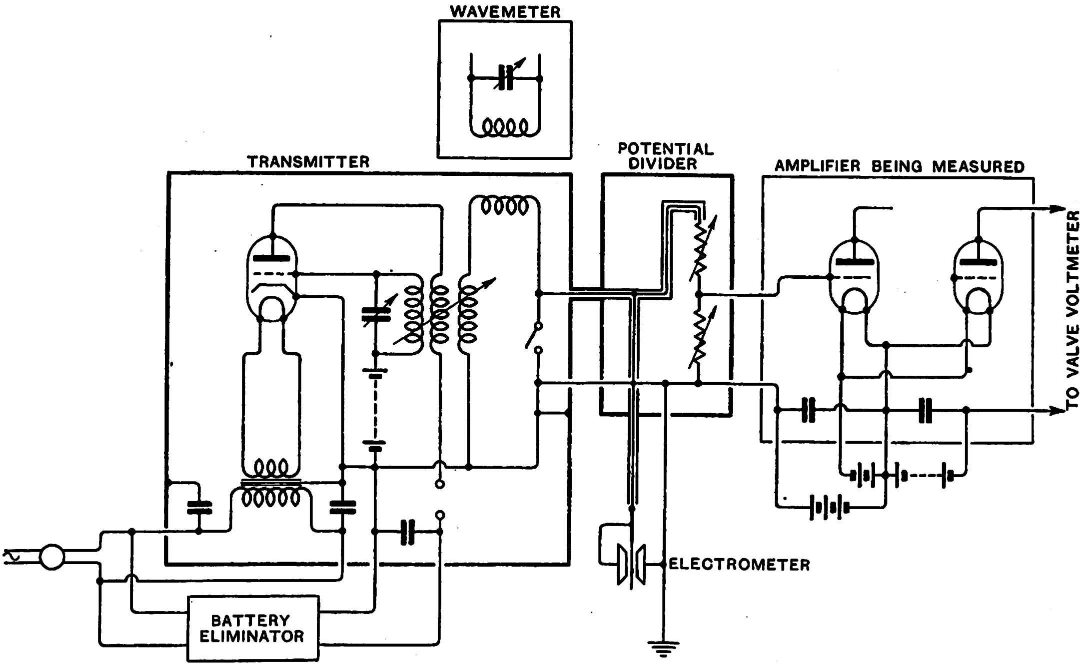


Fig. 6.—*Circuit of complete equipment.*

* Because of its great sensitivity and small input capacity.

to 10^{-5} volts can be determined. The complete apparatus used for these measurements is shown in Fig. 7, in which on the left, with the completely-screened aperiodic amplifier, is seen in the middle. It has been found possible to measure directly the voltages produced by distant transmitters in a small frame aerial tuned to resonance, and to carry out measurements of the field strength from distant stations. It has been found possible, for example, to follow the changes in intensity of the signals from many stations with time, and to take interesting curves of the voltage variations, which provide useful information for examining the phenomena of fading. As an example of this Fig. 8 shows a curve of the voltages of a transmitter at a distance of only a few hundred kilometres. The measurements show the typical variation of input voltage due to fading. In particular this arrangement was used to compare the intensity of different stations, during the evening hours, at the receiving station near Berlin. For this purpose an average value, representing a period of some six minutes, was obtained. Measurements of the field-strength of a stronger stations can, of course, be made without the need for a special amplifier.

Wireless Progress in the Past Two Years.

I.E.E. Wireless Section, Chairman's Address.

In his inaugural address as chairman of the I.E.E. Wireless Section on November 6th, Capt. C. E. Kennedy Purvis, R.N., reviewed wireless progress during the past two years. In the broad field of communications the merger between the Marconi and the Eastern Companies should lead to the development of Empire communications. A strategic need for cables still existed. An improved service was now being given by the Beam system, and short-wave channels to smaller colonies were in progress. At the same time long wave work should not be abandoned. In radio telephony the judicious use of long and short waves was giving a 24-hours transatlantic service, while other long-distance telephony systems were already in operation ; e.g., Holland–Java, Germany-Argentine, etc. Experiments on multiplex telephony and telegraphy on one channel were also in progress.

Amongst broadcasting matters, the Prague plan was a notable step. The previous Geneva and Brussels plans paved the way to the Prague plan, which was a formal agreement between Governments.

In the field of theory our knowledge of the mechanism of propagation had been greatly advanced by the work of the Radio Research Board and of the Marconi Company, and the lecturer reviewed the effects of the ionised layer on various wavelengths ; dealing with scattering, fading, interference and rotation of polarisation. The layer was a complex structure, and there appeared, in fact, to be two layers, one at 250 k.m. and one at 100 k.m. A notable feature was the development of aerials and apparatus for short waves, especially the Adcock direction finding system. On short waves it was possible to d.f. a nearby station with a ground ray. In the " skip distance " the scatter effect precluded d.f., but at greater distances, with a single indirect ray, d.f. again became possible. At very great distances there was, of course, the possibility of the waves arriving by several routes.

As regards apparatus, the H.T. generator schemes of Rugby and the B.B.C., were giving satisfactory performances. The rectifier scheme of H.T. supply gave perhaps greater security from " flash over." A slide was shown of valves for short wave transmitting purposes. Frequency constancy had been well solved for Rugby and the B.B.C. (on shared wavelengths) by the use of valve-maintained forks for the long and medium waves. For short waves master oscillators or quartz crystals were available, and it was hoped that the study of the quartz oscillator might evolve a source which was stable in frequency to 2 parts in a million.

Amongst receivers, the screened grid valve and the pentode were features of development, while moving coil loud speakers had made notable advances in the period under review. In short wave receivers better screening was a notable feature, but at frequencies above 8,750 k.c./s. little progress had been made. Other developments in apparatus included picture transmission systems, such as that of the Marconi Co. and the Fultograph, while television broadcast was now actually in operation. In directional working, the R.A.F. rotating beacon had been developed for aircraft and marine navigation, and a beacon of this type had been installed at Orfordness. Fixed beacon systems were also briefly reviewed, including experimental systems of sound and wireless emissions. In mercantile marine apparatus spark transmitters were vanishing, being replaced by I.C.W. on the 600-800 m. range. Short waves were also being put to maritime use.

The lecturer then reviewed the work of the Comité Consultatif International, Radio (C.C.I.R.), and outlined the subjects of discussion at the committee's recent conference at the Hague. The committee was intended to bridge the gaps between international conventions, the next of which was due at Madrid in 1932.

In connection with future work, the speaker suggested the need for the development of the very high frequencies, i.e., above 30,000 k.c., and the need for valve development for short-wave working generally. Frequency stabilisation was a matter of the greatest importance, and methods of automatic control of gain to compensate for fading were another problem for future solution. The hope of material improvement in the immumity from atmospherics seemed small on the longer waves, but was not so serious in the short wave region.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Experimental Transmitting and Receiving Apparatus for Ultra-Short Waves.

To the Editor, E.W. & W.E.

SIR,—In their interesting and comprehensive review of the above subject in the October issue of *E.W. & W.E.*, Dr. Smith-Rose and Mr. McPetrie point out that an oscillating valve circuit employing a single *LC* circuit is symmetrical about the D.C. supply (or, to be quite general, about *a* D.C. supply—that is, either grid or anode), and can therefore be represented by a symmetrical bridge network. The writer would suggest that the bridge shown in Fig. 8a for the particular circuit of Fig. 8 (page 538 of *E.W. & W.E.* for October) is not the most satisfactory way of showing this. First, the bridge shown is not generally applicable to circuits of this type and, secondly, the bridge in this particular case is *not* symmetrical as it is definitely stated in the text that the capacity of the anode stopping condenser forming one capacity branch of the bridge is greater than the grid-anode capacity forming the other and this would certainly usually be the case in practice. It is suggested that for the general type of circuit shown in Fig. 1 the most convenient bridge arrangement is that indicated in Fig. 2. Here two arms of the bridge are formed by the anode-filament and grid-filament capacities (C_{ga} forming a shunt across the "output" terminals of the bridge) and the other two by the two parts into which the nodal points of the capacity and inductance divide the oscillatory circuit. The existence of these nodal points is not, of course, dependent on whether actual connection is made to either or both of them, and the two *LC* circuits which represent the oscillatory circuit in the bridge diagram are the electrical equivalent of the single coil and condenser of the most common practical

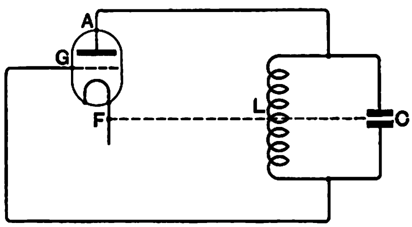


Fig. 1.

example of this circuit. It may be well to recall here that either the grid or anode D.C. supply may be introduced at the nodal point of the inductance and both may be if a stopping condenser of low impedance is introduced at the nodal point. Incidentally, this last scheme was not mentioned in the paper referred to, but it is worthy of note as being the only single *LC* circuit arrangement which avoids making any D.C. connection to a point of high alternating potential through a choke or high resistance. It does, however, introduce certain difficulties of its own. Returning to the bridge of Fig. 2, since C_{af} and C_{gf} are not in general equal, it is evident that the balance of the bridge will be upset if both the filament and the geometrical centre of either the inductive or capacitative branch of the oscillatory circuit are connected to earth and the result of such unbalancing will be a flow of

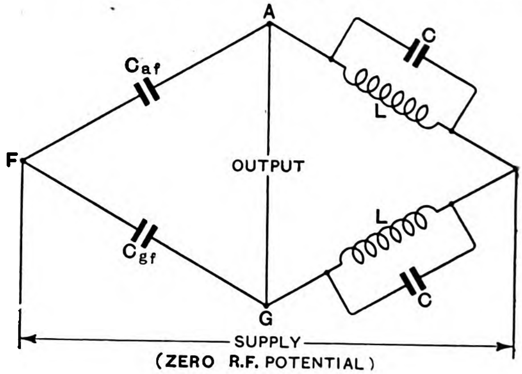


Fig. 2.

radio frequency current through parts of the circuit where it is neither useful nor desirable. The writer is of the opinion that much of the trouble and instability often experienced with ultra high-frequency oscillators is due to neglect of this point. This was confirmed by some recent experiments using the circuit in which the anode D.C. supply is connected at the nodal point of the inductance and the grid D.C. supply through a choke direct to that electrode. By using a small variable grid condenser (C_{gf} is usually greater under operating conditions than C_{af} and the condenser also serves to reduce grid circulating current) and an adjustable nodal tap a very satisfactory bridge balance could be obtained with any desired grid excitation and little or no trace of R.F. current in the D.C. supply circuits even at the highest frequencies. Compared with the usual centre-tapped coil arrangement a very gratifying improvement in purity and stability of the heterodyne note was noticed, particularly when rotary machinery was used for the H.T. supply. A 75-watt valve was used in these tests at frequencies ranging from 25 to 80 × 10^6 cycles.

E. C. S. MEGAW.
City and Guilds (Engineering) College,
South Kensington.
18th October, 1929.

To the Editor E.W. & W.E.

SIR,—Having read the first instalment of the paper by Messrs. Smith-Rose and McPetrie, dealing with their experiments upon the generation and

reception of ultra short waves, I looked forward with keen anticipation to the succeeding ones, with the idea of cribbing some useful information therefrom, it being much less trouble to obtain information from the work of others than to obtain same by one's own efforts, even if one is capable of so doing.

If the instalment contained in the current issue of *E.W. & W.E.* is the final one (as it appears to be), I must confess to a feeling of disappointment. One obtains the impression that much has been left unsaid, in this otherwise immaculate paper.

It will be inferred from the foregoing that I am particularly interested in this line of research.

I have been working upon somewhat similar lines during the past year, with the idea of developing a practical low-power apparatus for use on wavelengths of the order of 3 metres.

The points upon which I looked in vain for fuller information (seeking confirmation or otherwise of my own experiences) are set out below, together with my own (I hope not superfluous) comments.

(A) TRANSMISSION.

(i). *Screening of valve envelope.*

The use of metallic foil in close contact with the outside of the valve envelope is mentioned, but the authors apparently did not use it in their work, or investigate its effect.

I have found that, apart from its possible use as a preventive of possible puncturing of the glass envelope, it has a marked effect upon the performance of valves when used in ultra short-wave work.

I tried a large number of valves of different types (ratings up to 100 watts, all with glass envelopes, of course) for this work, and found that in every case the upper limit of frequency at which the valve would work was considerably raised by adopting this expedient.

To give an instance, a D.E.T.1. S.W., which could not by any means be induced to oscillate at a wavelength below 4.5 metres, worked quite efficiently at 2.7 metres when about 60 per cent. of the external surface of the envelope was covered by a coating of tinfoil pasted upon it.

This wavelength (or to be more precise 2.65 metres) was the lower limit on account of structural considerations, i.e., shortest possible length of external leads.

(A possible explanation of this effect of envelope screening is offered in a paper submitted to the Editor a short time ago.)

(ii). *Keying.*

The method used by the authors sounds extremely ingenious. Details of the actual arrangement would have been welcome.

In my own experiments with I.C.W. and telephony, grid circuit modulation being used, the only satisfactory method of keying I could think of was the well-known expedient of interrupting the primary current to the modulating transformer.

(iii). Why was the "push-pull" type of oscillator used (apparently) exclusively?

The reasons given by the authors do not seem adequate. (This form of circuit seems also to have been a favourite with many well-known Continental workers, many of whom are mentioned in the extensive bibliography given by the authors.)

(iv). *Feeders.*

Was there any particular reason for the use of the carefully spaced feeder shown?

I have found ordinary "cab-tyre" twin-twisted "flex" quite satisfactory in a practical outfit working on 2.8 metres. This latter form of feeder was used for both transmitter and receiver.

Was any difference noted in the aerial current obtainable (for a given input) with aerial

(*a*) Inductively coupled directly to oscillator.
(*b*) Inductively coupled via feeder to oscillator?

In my own experiments the results were as follows:—

On a wavelength of 2.8 metres.
Input to oscillator = 30 watts.

Aerial current (maximum obtainable at centre of half-wave "dipole"):—

(*a*) .1875 A.
(*b*) .15 A.

This difference could not be accounted for by radiation or resistance losses occurring in the feeder.

(B) RECEPTION AND WAVE PROPAGATION.

(i). It is not definitely stated in the paper whether pure or modulated C.W. was used in the tests.

(As the authors mention the use of "anode circuit modulation" in the case of the transmitters used by them, it was presumably the latter.)

(ii). Was heterodyne reception with pure C.W. found to be possible?

I did not try it, but used only modulated C.W.

(iii). What was the objection to super-regeneration?

My own experience was that it made all the difference between an apparatus only suitable for laboratory investigations and a practical working outfit.

Under average ground surface conditions the maximum ranges obtained were:—

Without super-regeneration	500 yards.
With super-regeneration ..	8,000 yards*
Mean height of aerials ..	7 feet.
Input to transmitter ..	20 watts.
Wavelength	2.8 metres.

Same receiver was used in both cases with same number of valves (self-quenching detector when super-regeneration was used).

(iv). Information in regard to the effect of the initial plane of polarisation of the waves and the relative amounts of absorption under different conditions would have been interesting.

The conclusions which I arrived at during the course of my experiments cannot very well be set out here, but are dealt with in some detail in the paper previously mentioned.

(v). No information is given about the ranges obtained, especially as regards the effect of using high power in getting signals "through" by "brute force."

*Longest range tried.

I have had no experience of the use (during range tests) of input powers greater than 30 watts, but even with this small amount of power signals were (using the super-regenerative receiver) *invariably* readable up to a radius of 1,000 yards from the transmitter, presumably owing to the "brute force" effect, because at greater ranges than this the presence of screening objects frequently interrupted communication.

In conclusion, I do not wish this communication to be construed either as an attempt to take the authors to task for their sins of omission, or, on my part, to pose as an exceptionally able investigator in this department of radio science.

I do hope that it is the purpose of Dr. Smith-Rose and his colleague to deal with the matter more fully in later papers.

C. WHITEHEAD.

S. Farnborough, Hants.

Moving Coil Loud Speakers.

To the Editor, E.W. & W.E.

SIR,—Mr. Cosens' letter in your November issue raises the question of priority, and the acrimony of disputes. My letter in the August issue neither raised the question of priority nor introduced the atmosphere of acrimony. I commiserated with Mr. Cosens in his labours due to delay in the publication of my analysis. I do not agree with his dates. The June *Phil. Mag.* supplement was in my hands on the first of that month and not one month later. It is obvious that both authors worked independently. I would indicate, however, that I outlined the theory of the M.C. in a lecture at Cambridge University in November, 1926. (Where was Mr. Cosens ?)

In writing scientific papers, references are a *sine qua non,* and one's inner consciousness is merely a useful reminder. Mr. Cosens has no excuse for not quoting references when he admits they exist.

So far as my book and articles in *The Wireless World* are concerned, I would point out that my main object has been to disseminate as much information as possible to the largest circle of people interested in radio. In so doing an author must write to the level of his readers. Neither my book nor *The Wireless World* were suited for the inclusion of highly technical matter. The academic mind usually jumps to conclusions—it seldom pauses to consider. In the preface of my book, line 7, I wrote, "The purely analytical side of the problem has not been broached, since it is beyond our present purview, etc." On p. 65 I wrote "The radiation of sound from a vibrating disc has been treated by the late Lord Rayleigh. The remarks which follow are based on an analysis by the author, in which Rayleigh's formulæ are incorporated." This analysis existed early in 1926 and had been read privately and checked by others. It was summarised in my *Phil. Mag.* and Roy. Soc. papers, from which it ought to be clear that I can think in differential equations as well as in vectors !

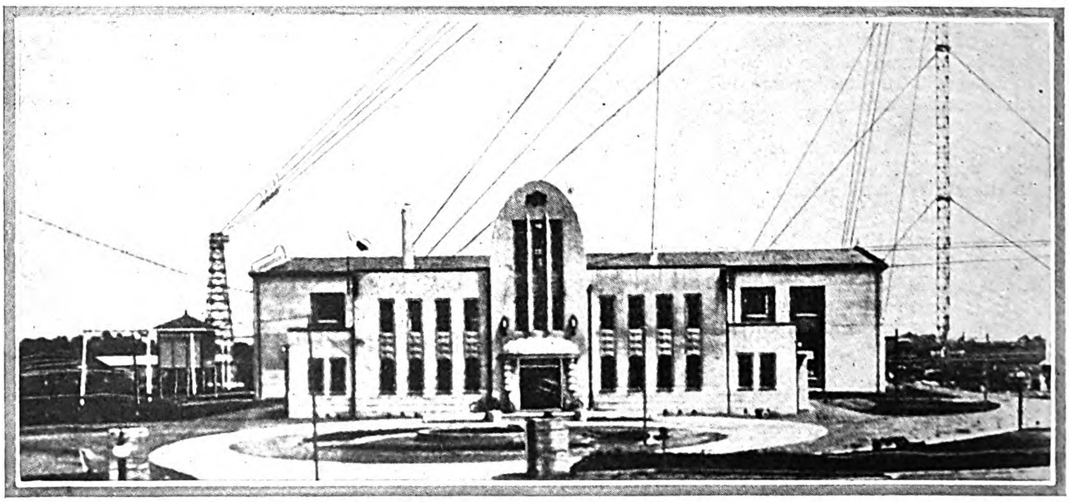
In his analysis Mr. Cosens has omitted the acoustic pressure distribution round the disc and the equivalent circuits of the M.C. which are useful in studying the physical properties of the device.

We are told that Rayleigh introduced "accession to inertia" in 1887. I gave this reference to Rayleigh on p. 65 of my book. What I said in August was that I introduced this subject into loud speaker design some years before the reference to which Mr. Cosens ardently adheres.

In *The Wireless World,* March 23rd, 1927, prior to the publication of my book, I gave a simple outline of M.C. theory. This embodied calculations on accession to inertia, etc., and the formula for the motional capacity. If Mr. Cosens had consulted this and other *Wireless World* articles his criticism against my book would not have materialised.

N. W. McLACHLAN.

London.



Station buildings at Nagoya Radio, Japan.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

PICTURE-RECEIVING SYSTEMS.

Application date, 28th April, 1928. *No.* 318117.

The screw-threaded spindle driving the feeler or recording stylus is fitted with a conical end-part. At the completion of each traverse the driving-wheel mounts the screw-threaded conical part, and lifts the feeler above the surface of the recording drum, thus preventing the possibility of damage due to drag on the rotating parts. The wheel is prevented from being entirely detached from the cone by running the last spiral into a circular groove.

Application date, 28th April, 1928. *No.* 318119.

The interior of the recording drum is fitted with a bobbin carrying a supply of sensitized paper. The end of the paper passes through a slit provided with a clamping device for stretching a fresh length of paper in position.

Application date, 28th April, 1928. *No.* 318120.

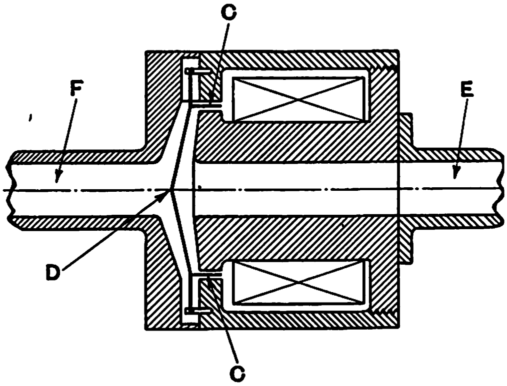
Instead of damping the sensitized paper prior to fixing it on the recording cylinder, it is mounted in a dry condition, and a capillary damping-wheel is arranged over the cylinder surface, just in advance of the feeler or recorder. This ensures a regular moistening action, and prevents "speckling" due to dry or semi-dry spots.

Patents issued to O. Fulton.

MICROPHONES.

Application dates, 1st June and 1st November, 1928. *No.* 318279.

Relates to a moving coil type of microphone, particularly sensitive to sibilants and similar high-



No. 318279.

pitched frequencies. The moving coil *C* is mounted on a shell fixed to the periphery of a conical diaphragm *D*, the angle of the cone being so selected that any disturbance originating at the centre of the diaphragm travels outwards to the periphery with the velocity of sound in air. The horn is attached to the inlet *E*, and the sound-waves pass round the periphery of the diaphragm and escape through the outlet *F*, the direction of ripple propagation set up in the diaphragm being the same as that of the passing air-waves.

Patent issued to F. W. Lanchester.

DRY-CONTACT RECTIFIERS.

Convention date (U.S.A.), 25th August, 1927. *No.* 296077.

The metal casing used to protect copper-oxide rectifiers from mechanical shock has the disadvantage of storing up the heat generated. According to the invention the sides of the casing are clamped into close contact with the outer radiating fins on the element, the necessary insulation being provided by a thin sheet of mica. This permits sufficient heat transfer to enable the whole of the protective cover to function as a heat-radiator. In addition the outer casing may be perforated to facilitate the free circulation of air.

Patent issued to The Westinghouse Brake and Saxby Signal Co., Ltd.

INDIRECTLY HEATED VALVES.

Convention date (Germany), 25th June, 1927. *No.* 308823.

The cathode or electron emitter is heated by conduction (as distinct from radiation) from the heating-element, which is formed as an extension of the cathode. The arrangement is such that the heating-current flows directly through the heating-element, but not through the cathode, the latter being shunted across points of equal potential on the current-supply leads.

Patent issued to S. Loewe.

Convention date (U.S.A.), 29th September, 1927. *No.* 297847.

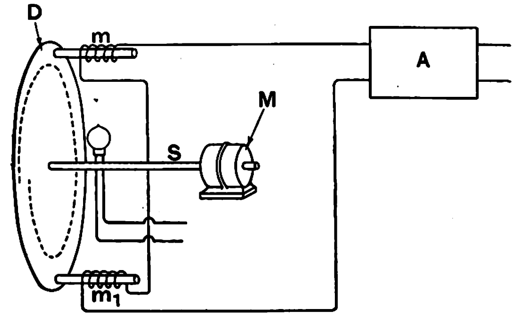
In a valve of the .8 type, taking raw A.C. direct from the mains, the fluctuating current through the filament sets up a corresponding magnetic field which deflects the flow of the electron stream from filament to plate, so creating plate current fluctuations which have the frequency of the mains supply. In order to compensate for this effect an auxiliary winding, in series with the filament, is mounted inside or outside the glass bulb, and is so adjusted as to produce an equal and opposite magnetic field to that of the filament.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

TELEVISION SYSTEMS.

Application date, 31*st May*, 1928. *No.* 318278.

In a combined television and telephony system, the usual exploring-disc is made to act also as the diaphragm of the loud speaker. As shown in the



No. 318278.

Figure, the exploring-disc D, fitted with a spiral series of holes, is rotated by a motor *M*. A series of magnets *m*, m_1, etc., mounted around the outer periphery of the disc, apply impulses of audible frequency from the amplifier *A*. The disc may be splined to the driving-shaft *S* to permit the slight longitudinal movements which occur in sound reproduction, the restoring force being provided by a spiral spring (not shown). Or the disc may consist of a peripheral strip of metal combined with a central portion of fabric or other yielding material, in which case no restoring spring is necessary, as the rotation of the device will tend to maintain it in the plane of rotation.

Patent issued to J. L. Baird and Television, Ltd.

Application date, 22*nd June*, 1928. *No.* 318331.

A stream of electrons is produced from a photo-electric surface, upon which the image to be reproduced has been projected, so that the density of the stream at each unit area of its cross-section varies with the light-intensity existing on the photo-electric surface. The electron stream is then traversed, by magnets or otherwise, over a conductor so that each unit area of cross-section sets up corresponding currents, which are then used to modulate a carrier wave. In reception the incoming signals are first rectified and after being amplified are applied to control locally generated currents in synchronism with the transmitter.

Patent issued to C. E. C. Roberts.

Application date, 1*st June*, 1928. *No.* 318565.

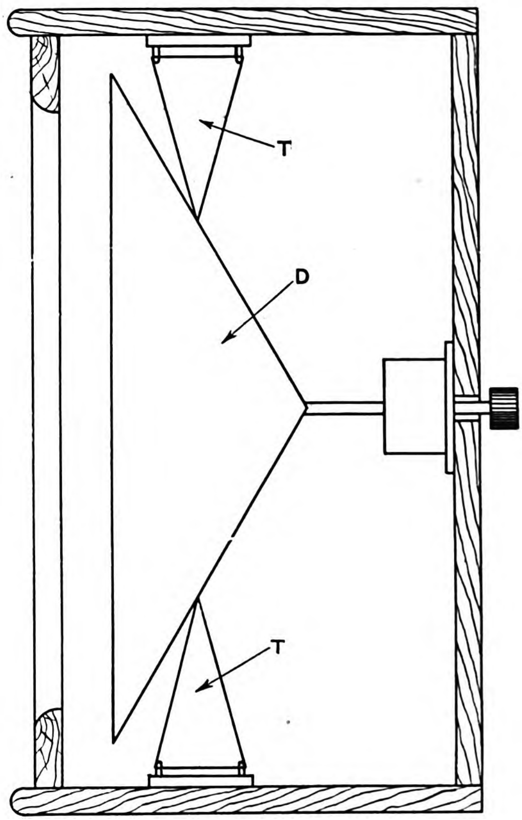
Cathode rays are used for scanning both at the transmitting and receiving ends. At the transmitter the rays energise a photo-electric plate so arranged that the image to be transmitted is projected simultaneously on the opposite face of the plate, and a control current, which corresponds at any moment to the light-intensity of each particular picture-element, is transmitted through the plate, at the point on which the cathode ray impinges at that moment. At the receiving end the cathode ray traverses a fluorescent screen, producing visible effects corresponding to the original picture. By projecting three images simultaneously in the three primary colours at the transmitter, natural-colour reproduction is secured at the receiver.

Patent issued to J. E. Pollak.

LOUD SPEAKERS.

Application date, 23*rd July*, 1928. *No.* 316007.

The diaphragm *D* is supported or poised at a number of points, preferably three, lying in a plane at right angles to the axis of the diaphragm and passing approximately through its centre of gravity. The suspension consists of a system of threads *T* forming at each points of support the apex of an isosceles triangle. The base of the triangle is carried by a bracket mounted on the inner walls of



No. 316007.

the casing as shown. As both sides of each triangular suspension are resilient and are initially in tension, any axial movement of the diaphragm as a whole will increase the tension on one side and decrease it on the other, thus ensuring a compensating action by which any damping effect is minimised.

Patent issued to A. P. Welch.

TELEVISION SYSTEMS.

Application date, 4th January, 1928. No. 314591.

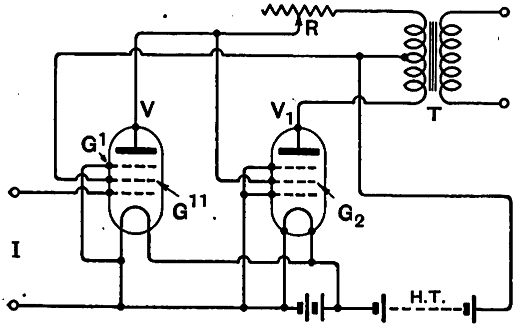
For securing coloured effects at the receiving end, the object at the transmitter is explored by a spot-light of the same, or substantially the same, colour as the object itself. For two-colour or three-colour reproduction a plurality of spot-lights of corresponding colours are used, the periods of exploration being separate and consecutive; or they may overlap, or be concurrent. A corresponding number of light-sensitive cells are used, the various cells being so selected as to be particularly selective to each primary colour. In reception the synthesizing-disc is provided with three separate spirals of lenses each covered by equivalent light filters.

Patent issued to J. L. Baird and Television Ltd.

PENTODE AMPLIFIERS.

Application date, 4th April, 1928. No. 314605.

As shown in the diagram the input circuit *I* is connected to the control grid of a pentode valve *V*. The second grid G_1 is connected to the filament, and the third grid G^{11} to the high-tension battery *H.T.* as usual. The anode of the valve *V* is connected directly to the grid G_2 of a second pentode



No. 314605.

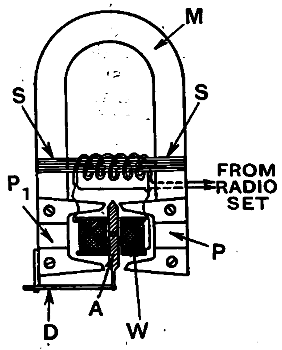
V_1, and, through a variable resistance *R* and part of the primary of a divided output transformer *T*, to the high-tension battery *H.T.* The anode of the valve V_1 is taken to positive H.T. through the lower winding of the transformer primary. Both the other grids of the valve V_1 are connected to the filament, as shown. This arrangement gives an effective push-pull amplification for operating a loud speaker. It will be noticed that no insulated grid battery is employed, the presence of which under certain conditions of working is often a source of trouble.

Patent issued to J. S. C. Salmond and L. S. B. Alder.

LOUD SPEAKER MOVEMENTS.

Convention date (U.S.A.), 18th November, 1927. No. 300620.

An armature *A*, pivoted at its centre, is vibrated between upper and lower extensions of the polepieces *P*, P_1, and communicates its movement to a rod *D* connected to a diaphragm. The novel feature lies in applying the low-frequency energising-current to a soft-iron shunt *S* bridged across the



No. 300620.

permanent magnet *M* as shown. The effect of the induced magnetism is to strengthen or weaken the magnetic flux across the polepieces *P*, P_1, thus vibrating the armature. Preferably the magnetic shunt *S* is used in combination with an energising-winding *W* surrounding the armature *A* as usual.

Patent issued to I. Kitsée and D. C. Law.

SOUND HORNS.

Application date, 3rd July, 1928. No. 315561.

With the object of securing balanced emission of both high and low notes from a horn of comparatively moderate length, the horn is so made that its area increases in geometrical proportion along a number of successive sections, *i.e.*, it is doubled at the end of the first stage, trebled at the end of the second, and so on. At the same time, the overall length of each of these sections diminishes in arithmetical proportion from the input to the output. This gives a gradual increase in area at the input end of the horn followed by a comparatively rapid increase towards the open end.

Patent issued to R. L. Aspden.

GRAMOPHONE PICK-UPS.

Application date, 19th April, 1928. No. 315488.

The volume of sound produced by the pick-up is controlled by means of a variable magnetic shunt inserted across the polepieces of the magnet. In one construction two pairs of grooves are formed at the point and rear of each leg of the magnet These accommodate two sliding plates of soft iron. As one or both plates are moved down, by hand, towards the ends of the magnet legs, the effective flux across the polepieces is reduced. This causes a diminution in the voltage induced by the movement of the stylus, and a corresponding decrease in the intensity of sound.

Patent issued to P. D. Tyers.

AN ACOUSTIC VALVE-AMPLIFIER.

Application date, 4th May, 1928. *No.* 315040.

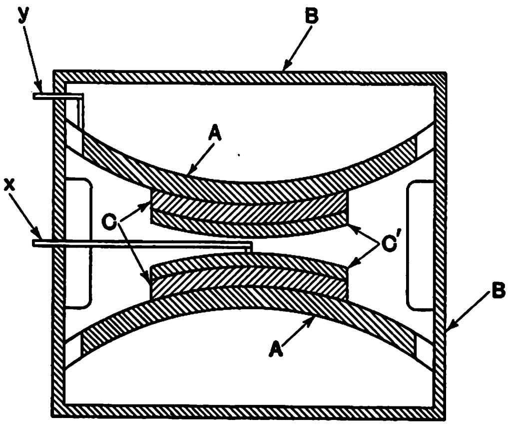
A three-electrode amplifier is adapted to effect a direct conversion of electric current into sound waves by utilising the temperature changes generated in the anode of the valve owing to the fluctuating electron stream. The anode consists of a thin metallic sheet sealed into the crown of a flat-topped bulb. One surface of the anode is open to the air, and to this surface is secured a perforated sheet of non-conducting material fitted with projecting flanges to form an air-chamber or resonator. As the value of the plate current through the valve varies, temperature changes on the exposed surface of the anode are communicated to the adjacent film of air, and set up corresponding waves of sound.

Patent issued to B. S. Cohen.

LIGHT-SENSITIVE CELLS.

Application date, 3rd April, 1928. *No.* 314838.

Powdered selenium, alone or mixed with powdered tellurium, phosphorus, uranium, thorium, and certain other metals, is compressed into a coherent mass, which may be heated in an atmosphere of inert or reducing gas, or *in vacuo*. This is stated to increase its reaction to light. The prepared



No. 314838.

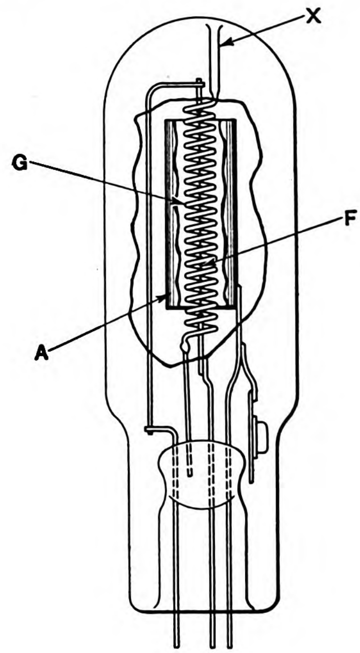
sensitive material may be moulded into a concave cylinder *A*, and mounted inside a glass casing *B*. A brush-like formation of wires *C*, attached to a metal backing-plate *C'*, forms a central contact for the electrode *x*, the other electrode *y* being arranged at the other edge as shown.

Patent issued to C. Ruzicka.

ACTINO-THERMIONIC AMPLIFIERS.

Convention date (U.S.A.), 19th August, 1927. *No.* 295702.

The grid *G* of a thermionic valve is made of a solid spiral of quartz or optical glass, having a monatomic coating of cæsium or other photo-electric metal. The upper end is fused into the glass bulb at *X*. A ray of light directed on to the upper end will traverse the quartz rod from end to end in a series of internal reflections. At each



No. 295702.

reflection photo-electric emission takes place from the spiral surface, thus raising the effective potential of the grid and increasing the electron stream from the central filament *F* to the cylindrical plate *A*. For any particular value of applied light-intensity, the loss of electrons by photo-electric action from the grid is balanced by fresh electrons received from the filament, so that the grid attains a definite potential.

Patent issued to British Thomson-Houston Co., Ltd.

ELECTROLYTIC CONDENSERS.

Application date, 29th March, 1928, *No.* 314565.

An electrolyte of jelly or paste-like consistency is used, preferably sodium silicate and a solution of sulphuric acid. This is placed in a container which is chemically inactive to the constituents and which is not a film-forming metal. The positive electrode is of tantalum, the container forming the negative electrode. The separators are of glass, porcelain, or hard rubber. The whole is sealed by paraffin, which is sufficiently porous to allow of the escape of gases formed when the cell is in action.

Patent issued to Standard Telephones and Cables Ltd.

MEASURING MECHANICAL IMPEDANCES.

Application date, 30*th March*, 1928, *No*. 314575.

The mechanical impedance of a body is defined as the force in dynes applied to the body divided by the velocity in centimetre seconds units with which the body is moved. The mechanical reactance is defined as the component of the mechanical impedance which is 90 degrees out of phase with the applied force, either lagging or leading. The mechanical resistance is the component of the mechanical impedance in phase with the force. The absolute value of the mechanical impedance is measured in mechanical ohms.

According to the invention the mechanical impedance of a system is measured directly by a hybrid bridge of the Rayleigh type, partly mechanical and partly electrical, consisting of a variable resistance calibrated to read directly in mechanical ohms, and a variable elasticity member for counteracting the mechanical reactance of the system. The element of the bridge which in operation is coupled to the apparatus under test consists of a moving coil mounted in the centre of a steady magnetic field by means of three tension members so as to ensure a single degree of motion.

Patent issued to W. E. Beatty.

RECORDING BROADCAST.

Application date 5*th May*, 1928. *No*. 314638.

In order to make a permanent record of any particular item in a Broadcast programme, a sound-recording attachment is linked up to the output of the Broadcast receiver, and switching means are provided whereby the recorded item is conveniently connected up to the input of the amplifier, so that the record can be repeated as desired. The recording outfit is preferably of the telegraphone type, in which the received and amplified currents are made to produce characteristic magnetisation on a hard steel disc. This when applied to the poles of a reproducing coil serves to generate currents similar to those originally produced. Since the current taken by the reproducing apparatus is very small, the latter is branched off in parallel with the loud-speaker leads, so that the desired item may be both heard on the loud speaker and recorded in permanent form simultaneously.

Patent issued to E. Shipton.

REPRODUCING SOUNDS.

Application date, 13*th July*, 1928. *No*. 318708.

Sounds are reproduced by thermo-electric variations of pressure created inside a pipe or conduit. A continuous flow of air is set up inside the pipe, the air passing over a thin silver grid connected in series with the primary winding of a step-down transformer fed by a wireless amplifier. Variations in transformer voltage create temperature changes in the silver grid, which in turn superimpose corresponding pressure-variations, forming sound waves, on the passing air-stream.

Patent issued to Consulting and Radio Service Ltd., and N. Turner.

PREPARING PIEZO-ELECTRIC CRYSTALS.

Application date, 6*th July*, 1928. *No*. 314680.

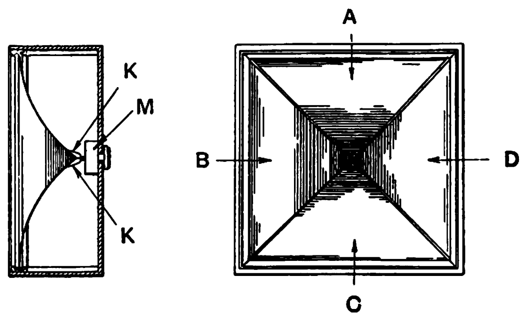
Rochelle salt crystals as usually prepared are characterised by the formation of opaque or porous regions at each end, to which the term "hour-glass" is usually applied. These regions contain occluded mother liquid, and are very difficult to dry up even under intensive dessication in absolute alcohol. When the crystal has been in use for some time there is, however, a gradual decrease in electrical conductivity owing to spontaneous evaporation, with a consequent impairment of the piezo-electric action. According to the invention, the hour-glass regions are dried out by boring drain-holes in them from the base of the crystal. The crystal is then mounted in a suitable container and subjected to compressed air. The dried-out parts are afterwards rendered electrically conductive by applying an aqueous solution of silver nitrate. On exposure to light this deposits a film of metallic silver which serves as an electrode.

Patent issued to E. W. C. Russell.

LOUD SPEAKERS.

Application date, 19*th July*, 1928. *No*. 314691.

The diaphragm consists of four triangular or sector-shaped membranes *A*, *B*, *C*, *D*, clamped at their outer edges and bent inwards to form a cone. The membranes are so cut that the curved radial edges do not come into close contact, but leave a narrow gap as shown. The ends are folded in the direction of the axis so as to form radial ribs *K* near the apex, which serve to stiffen the diaphragm as a whole. The driving-reed of the movement *M*



No. 314691.

is attached at the point of intersection of the ribs *K*. In operation the curvature of each sector decreases and increases alternatively, causing the edges to converge and diverge. The gaps are made as narrow as possible, so that, whilst affording the requisite freedom of movement to each individual membrane, undue loss in efficiency due to leakage of the air waves from the front to the back of the diaphragm is minimised. In an alternative construction, the gaps between the edges are covered over by thin strips of flexible material, such as soft leather glued to the back of each sector or membrane.

Patent issued to H. Birkbeck.

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STATIONS, DESIGN AND OPERATION.

GENERAL PHYSICAL ARTICLES.

MISCELLANEOUS.

EXPERIMENTAL WIRELESS

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The WIRELESS ENGINEER

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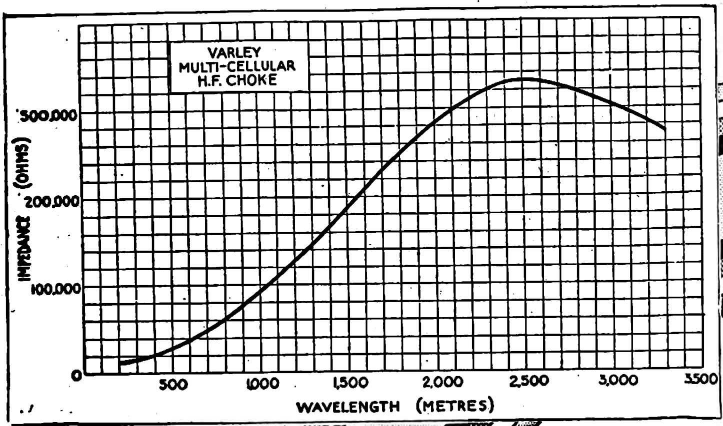

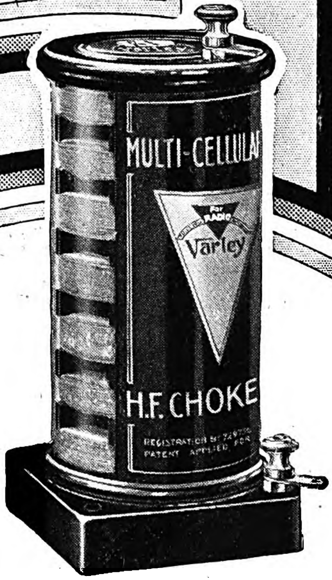

Look at the impedance frequency curve of practically any other H.F. Choke. What do you see?—a series of small peaks pointing to the presence of minor resonances.

This means that, suitable as they may be for use in the anode circuit of a reacting detector valve, they cannot be considered for a parallel feed circuit.

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